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IS 14580-2 (2006): Use of network analysis for projects management, Part 2: Use of graphic technique [MSD 4: Management and Productivity]

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परियोजना प्रबन्ध के लिए नेटवर्क विश्लेषण का प्रयोग

भाग 2 रेखीय तकनीक का प्रयोग

Indian Standard

USE OF NETWORK ANALYSIS FOR PROJECT MANAGEMENT

PART 2 USE OF GRAPHIC TECHNIQUES

ICS 03.100.40

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FOREWORD

This Indian Standard (Part 2) was adopted by the Bureau of Indian Standards, after the draft finalized by the Management and Productivity Sectional Committee had been approved by the Management and Systems Division Council.

A project is described as a one time activity with an identifiable beginning and an identifiable end unlike other routine activities that are repetitive. It has a well defined purpose and scope and a definite set of separate but interrelated and interdependent activities that must be completed to achieve the objectives for which the project is instituted. It has a well defined project product, including product performance criteria and well defined completion criteria.

This standard is published in two parts. Other part in the series is:

Part 1 Management, planning, review, reporting and termination procedures

Part 1 of this standard dealt with the basic aspects of project management that were applicable to the projects from conception to completion/termination using network techniques.

Project network techniques as used now, have developed since the mid 1950s. These developments include both activity-on-arrow and activity-on-node systems. The technique as developed aimed at improving the ability to plan and control complex engineering projects and was called Critical Path Method (CPM). Probabilistic elements appropriate to the research and development (R&D) area were also included in a modified technique called Programme Evaluation and Review Technique (PERT). This standard provides guidance on the factors that are to be considered while choosing between the various networking techniques. It deals with the drawing methods to be used for presentation of these techniques and in particular for presentation of activity-on-arrow and activity-on-node diagrams including the conventions to be used.

Activity-on-arrow networks were quite popular in the manual handling of networks. With the increasing use of computers for processing, activity-on-node or precedence networks have now become more popular. A number of ready-made software packages are available for use on computers which provide support not only for planning but also for updating and monitoring of progress from time-to-time. The technique has since been extended to handle scheduling of resources, uncertainty of outcome as well as duration and many other specific parameters.

Systems based on network analysis provide various advantages over the conventional methods of planning and control based on bar charts. These advantages may include:

a) Clearer definition of the scope of the project and the complex interrelationships between its constituent activities;
b) Better coordination between different agencies engaged in the project and provision of information about each agencies progress and future plans to the others;
c) Ease of preparing schedules of activities and adjusting these schedules to last minute developments;
d) Ready means of reviewing the project and exercising control over time, resources and costs; and
e) Clearer identification of critical and risk areas, besides providing an excellent model for generating 'what-if' scenarios for making management decisions.

Indian Standard

USE OF NETWORK ANALYSIS FOR PROJECT MANAGEMENT

PART 2 USE OF GRAPHIC TECHNIQUES

1 SCOPE

This standard (Part 2) deals with the various graphic techniques used in project management in its various aspects and during its various phases of execution. The methodology of using these various graphic techniques as covered in this standard, include the following:

a) Bar charts (Gantt charts),
b) Milestone charts,
c) Activity-on-arrow charts,
d) Activity-on-node charts,
e) Squared network,
f) Histogram,
g) Time variance charts,
h) Cost variance charts,
j) Resource utilization charts, and
k) Resource productivity charts.

2 REFERENCE

The following standard is a necessary adjunct to this standard:

IS No.	*Title*
IS 14580 (Part 1) : 1998	Use of network analysis for project management : Part 1 Management, planning, review, reporting and termination procedures

3 BAR CHARTS

3.1 A bar chart is one of the easiest, convenient and most widely used means of graphical display of project activities on a time scale. A bar chart can be used both for displaying the plan and status report to track and monitor progress and provide important feed back to the team members for appropriate action. It is a two dimensional representation showing the various activities on the vertical axis and their time on the horizontal axis. IS 14580 (Part 1) may also be referred for guidance in graphical representation pertaining to typical bar charts.

3.2 Typically a bar chart is drawn on a single sheet so that the entire project and the accompanying set of activities including the project goal can be seen at a glance. A bar chart for an entire project, groups many activities together and may also show major events/milestones.

3.3 For drawing the bar chart, start with listing down the activities along with their time duration. Depending on the project duration and duration of each of the activities, a suitable time scale may be selected. A bar chart would then be drawn as a two-dimensional representation of various activities of the project plotted on the vertical axis and their duration flowing from left to right on the horizontal axis.

3.4 Bar charts can also be drawn to reflect resource scheduling, where instead of listing activities in rows in the left margin, these are substituted with the name of the specific resource element like persons responsible, department names or pieces of equipment. Clause **9** pertaining to resource utilization charts can be referred for more details.

3.5 Figure 1 shows representation of a bar chart pertaining to a simple house building project. The lower line with troughed ends represent scheduled start and the scheduled finish of the planned progress, while the darker upper straight line represents the part of activity that has been completed as on the date of review. The review point in Fig. 1 reflects the status of various activities at the time of review. A review of the status indicates that though excavation started a bit late but was completed on time. The foundation work was completed ahead of schedule. The superstructure activity though started ahead of schedule, went beyond planned schedule, thereby delaying the start of the roofing activity.

3.6 The value of bar chart can be further enhanced by quantifying the total work for an activity and also allocating appropriate quantities on the bar for each time unit. This quantity could be in terms of physical parameters like as shown in Fig. 2 or in financial terms as shown in Fig. 3.

3.7 Incorporating the quantity of each activity, in relevant measurement units, with their planned/actual periodic break-ups under or over the respective bars can further enhance the usefulness of a bar chart. This has been shown in Fig. 2, which depicts physical progress quantified bar chart. Figure 2 is also called the milestone bar chart (*see* **3**). Depiction of milestones

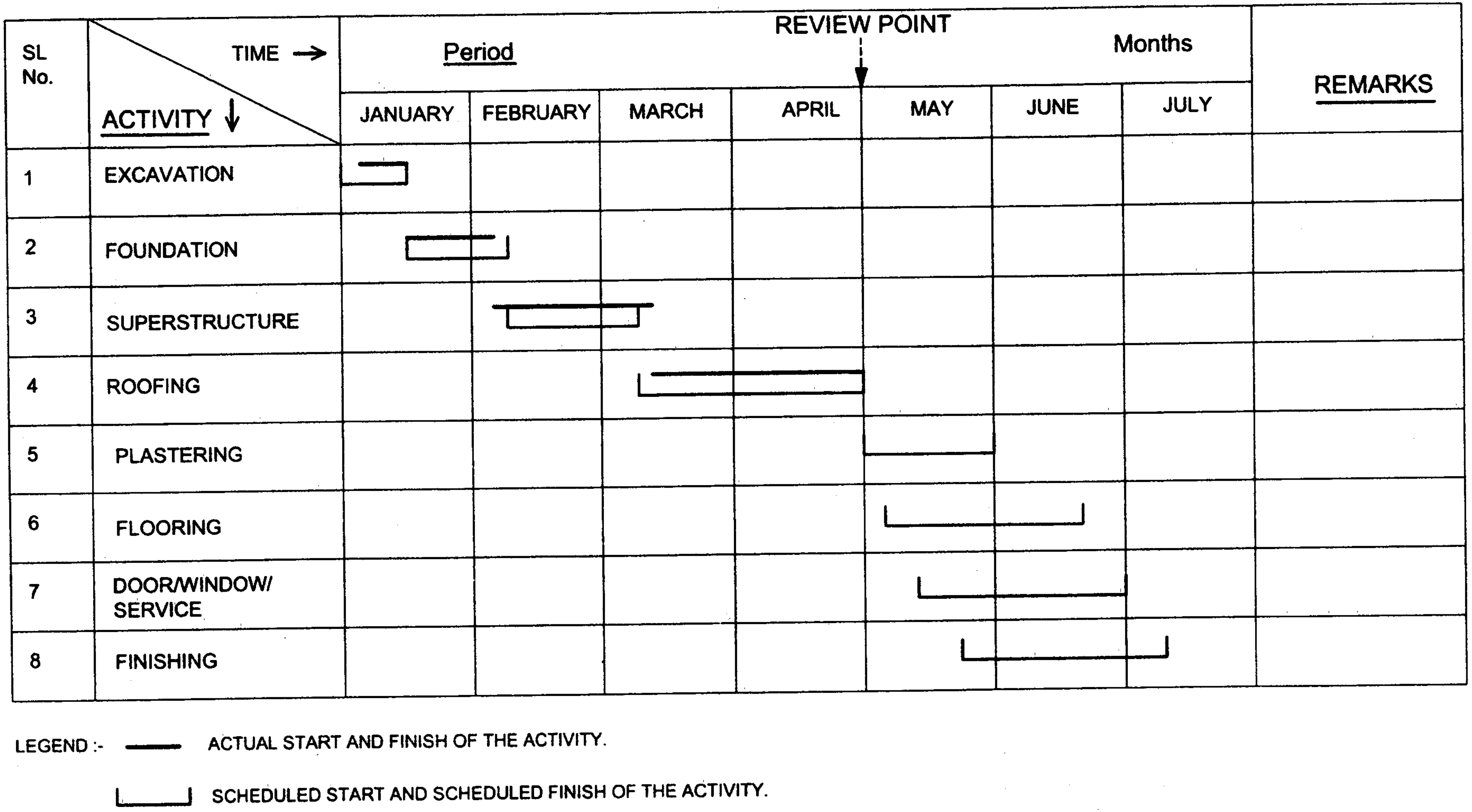
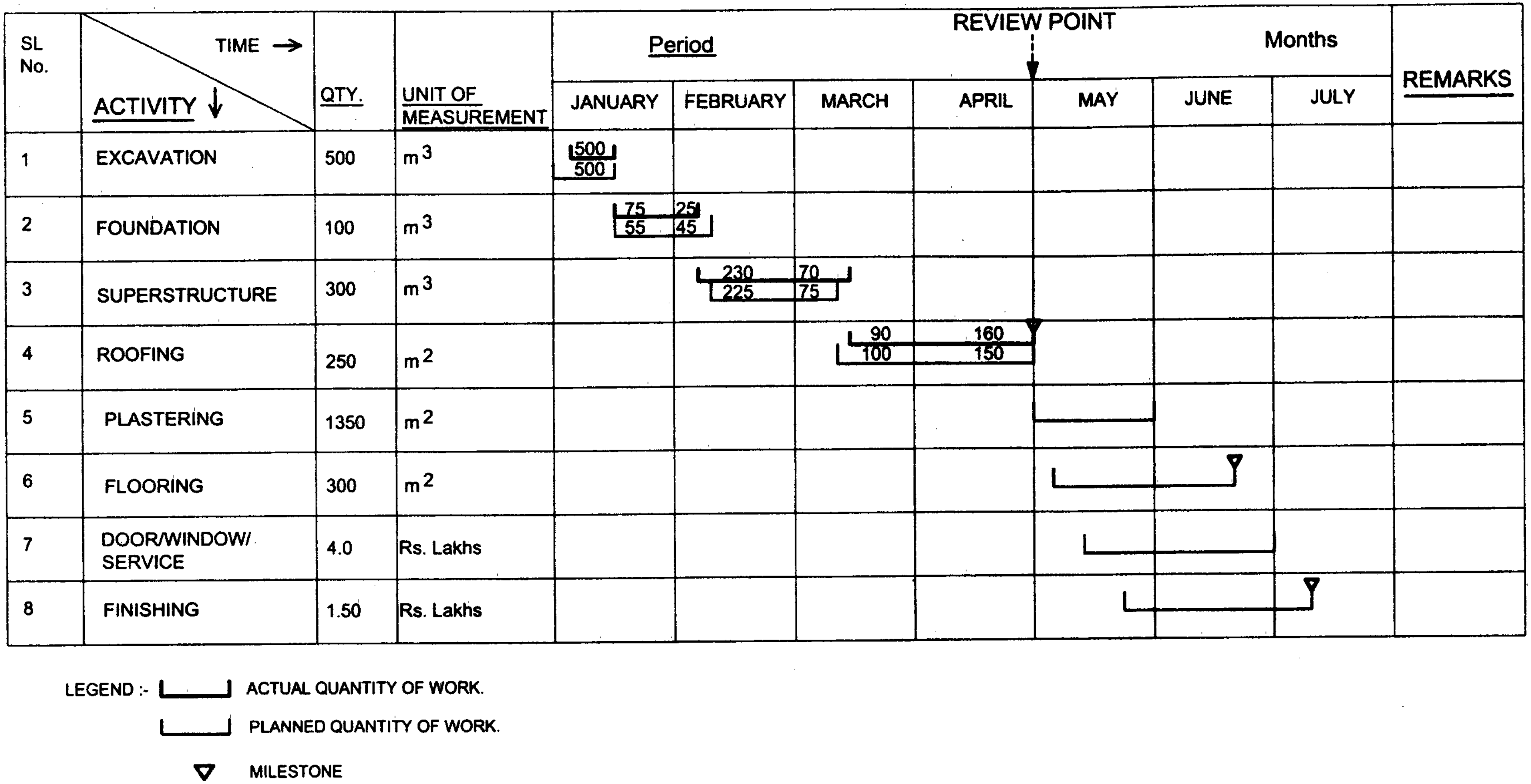


FIG. 1 BAR CHART FOR CONSTRUCTION OF A HOUSE SHOWING STATUS — PLANNED *versus* ACTUAL COMPLETION TIME AT THE REVIEW POINT



SL No.	ACTIVITY	QTY.	UNIT OF MEASUREMENT	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	REMARKS
1	EXCAVATION	500	m^3	500 500							
2	FOUNDATION	100	m^3	75 55	25 45						
3	SUPERSTRUCTURE	300	m^3		230 225	70 75					
4	ROOFING	250	m^2			90 100	160 150				
5	PLASTERING	1350	m^2								
6	FLOORING	300	m^2								
7	DOOR/WINDOW/ SERVICE	4.0	Rs. Lakhs								
8	FINISHING	1.50	Rs. Lakhs								

FIG. 2 MILESTONE BAR CHART FOR CONSTRUCTION OF A HOUSE SHOWING ACTIVITY-WISE PLANNED *versus* ACTUAL QUANTITIES COMPLETED AT THE REVIEW POINT

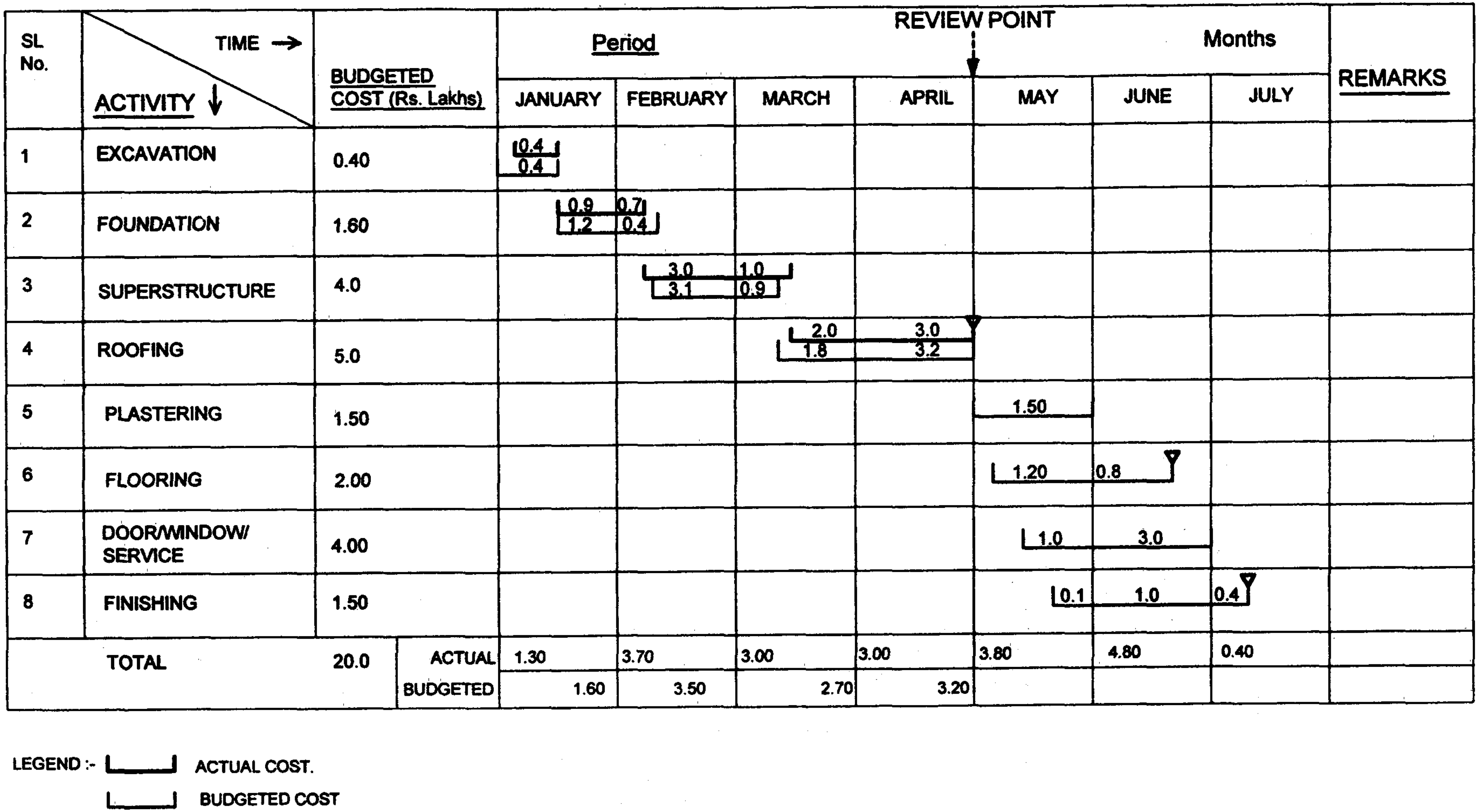


FIG. 3 BAR CHART FOR CONSTRUCTION OF A HOUSE SHOWING ACTIVITY-WISE BUDGETED AND ACTUAL COST BOOKED

on bar charts greatly enhances their usefulness, since the implications of any slippage in their accomplishment could lead to delay in project completion. They should be specified clearly and refer to completion of defined activities or major deliverables.

3.8 The health of a project can be gauged by tracking expected changes in the dates on which the milestone events are expected to occur. Appropriate corrective measures could then be taken to control the slippage, if any.

3.9 Figure 3 showing financial progress, presents a slightly different version of the same bar chart, in which the activities have been evaluated as per their budgeted cost provisions for the planned schedule and the actual cost booked for the part executed. The periodic (monthly in this case) summations in the bottom row of the forecast provisions and the actual cost incurred during execution reflect the overall picture of the performance of the project in financial terms. A review of the referred project as at end of April indicates achieved progress of 1.30 lakhs, 3.70 lakhs, 3.00 lakhs and 3.00 lakhs against corresponding planned targets of Rs. 1.60 lakhs, 3.50 lakhs, 2.70 lakhs and 3.20 lakhs for the months of January, February, March and April respectively.

3.10 A limitation of bar charts is that they do not contain dependency relationships. For small projects, these can be visualized but for bigger projects it may not be so.

4 MILESTONE CHART

4.1 In case of bar charts the assumption is that physical progress is only resource dependent. But in actual practice, the physical progress is not always resource dependent, there may be other dependency constraints. Milestone charts can eliminate this shortcoming of bar chart by associating percentage progress towards the completion of project with achievement of every milestone.

4.2 Milestones are event of significant accomplishment in the progress of the project. These events can be recognized by all concerned. These are physically verifiable and hence can form check points for evaluation and reporting of progress. For a project where final finished output is likely to be available only after a long time, the milestones can be treated as intermediate targets.

4.3 Forms of Presentation

4.3.1 Instead of indicating the progress to be achieved in the form of a bar, the milestones to be completed are shown on the chart in Fig. 4 in the form of an inverted triangle. The description of milestone may also indicate the percent progress of project achieved on completion of the milestone. Affixing the symbol at the actual row likewise shows the actual date of accomplishment of a milestone. For milestones yet to be accomplished, the anticipated completion date will be shown as hollow inverted triangle on the dotted line.

4.3.2 For example in Fig. 4 which shows the milestone chart for a small project involving placement of purchase order. The issue of order is scheduled in the month of July. This means that if the output of the group is measured in terms of the issue of this order, the measurable output would come only after 6 months. Now if the milestones involved in this work are scheduled as shown and if the percentage of total work involved upto a milestone can be settled in advance then on achievement of a milestone it can be assumed as if that fraction of the work has been completed.

4.3.3 Figure 4 shows the milestones completed as on end March, which is the review point. The requisition for item has been received in middle January as against target of beginning of January. Similarly receipt of bid has taken place in March as against schedule of February. As per this milestone chart, by end of April 'recommendation to client' milestone equivalent to about 85 percent of the work should have been completed. As against this only 'receipt of bid' milestone equivalent to 15 percent of the work has been completed. The projected completion date of the project gets shifted to August end.

4.3.4 A milestone by definition is an event which enables us to know when something should occur, but not what should be done to make it occur. For the total project the milestone chart can serve as a document giving an overview of the project and its status at any point of time. It is mostly used for providing information to senior management. Figure 5 shows a typical milestone chart of a long gestation period power project at the scheduling stage, wherein only major events of the project have been shown as milestones. The horizontal time scale is like a normal bar chart while the milestones have been listed in the column on the left side.

4.3.5 Another useful variation of milestone chart is the milestone slip chart. In this, while the horizontal time scale is like a normal bar chart, the vertical axis also represents time, with each line reporting a particular report/review date. The chart is read from top to bottom and allows us to see at a glance how dates of any specific milestone have slipped/recovered as the project progresses. A typical milestone slip chart is shown in Fig. 5 where the key events are the milestones.

DESCRIPTION	PROGRESS IN % IN TOTAL WORK DONE		Period			REVIEW POINT				Months		
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
RECIEPT OF REQUISITION	0 %	SCH	⊽									
		ACT	▼									
ISSUE OF ENQUIRY	5 %	SCH	⊽									
		ACT	▼									
RECIEPT OF BID	15 %	SCH		⊽								
		ACT			▼							
TECHNICAL EVALUATION OF BIDS COMPLETE	70 %	SCH				⊽						
		ACT/ANT					▽					
RECOMMENDATION TO CLIENT	85 %	SCH					⊽					
		ACT/ANT						▽				
ISSUE OF LETTER OF INTENT	90 %	SCH						⊽				
		ACT/ANT							▽			
ISSUE OF PURCHASE ORDER	100 %	SCH							⊽			
		ACT/ANT								▽		

LEGEND :- ⊽ SCHEDULED DATES
▼ ACTUAL DATES
▽ ANTICIPATED DATES

FIG. 4 MILESTONE CHART FOR PROJECT-PLACEMENT OF ORDER

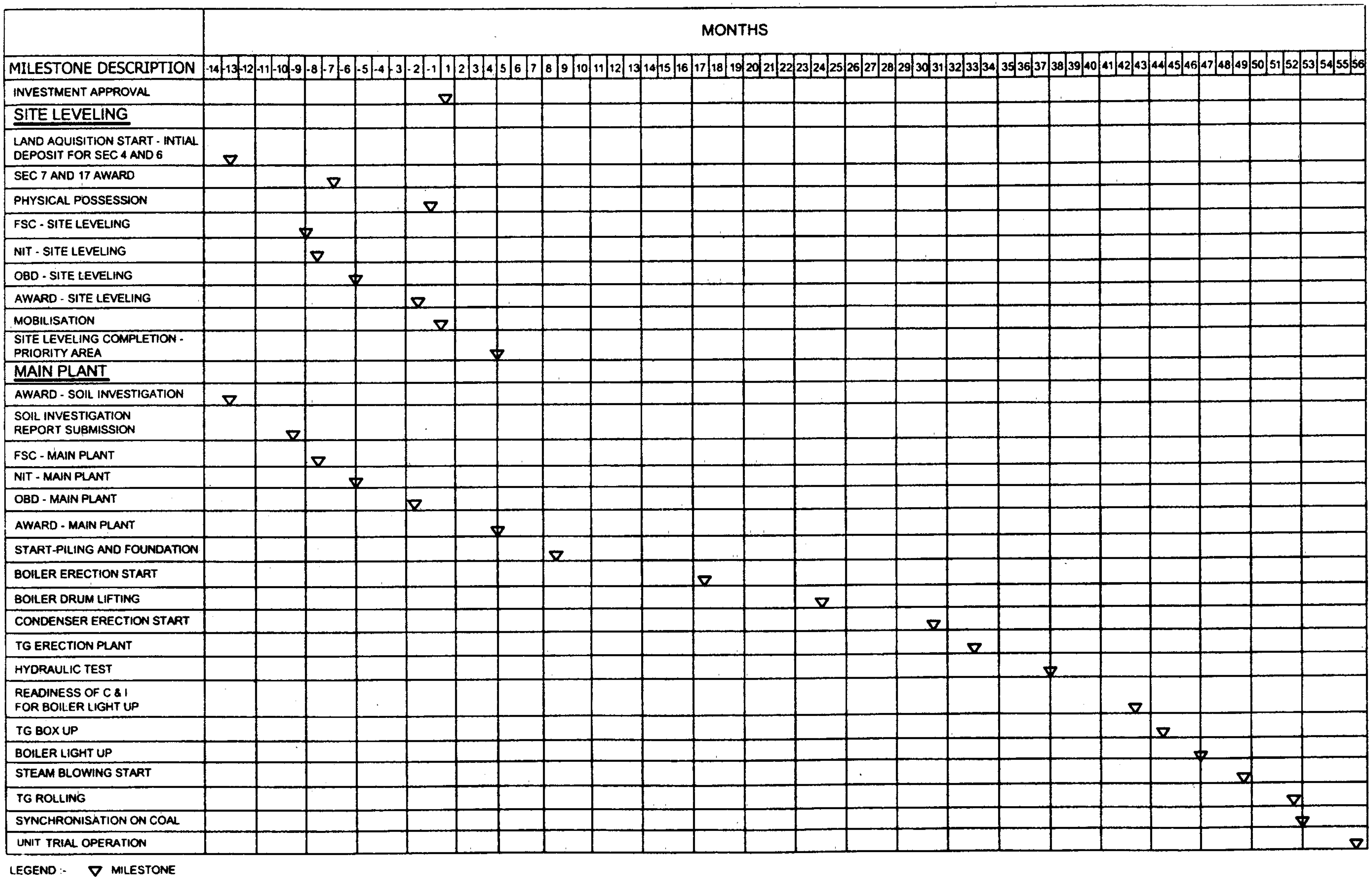
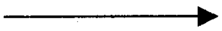


FIG. 5 MILESTONE CHART FOR A POWER PROJECT

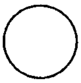
5 ACTIVITY ON ARROW NETWORK

5.1 There are two types of network used in the network technique. These are activity-on-arrow and activity-on-node. Activity-on-node network is also referred to as precedence network. Definitions of important terms used in activity-on-arrow network are:

a) *Activity* — An activity is a task or a group of tasks in the project which consumes resources and time. An activity is represented by an arrow.



b) *Event* — Event is a point of time in a project and is normally used to denote starting or completion of one or more activities and consumes no time and resource. Every activity is denoted by starting event or tail event and ending event or head event. An event is represented by a small circle.



c) *Dummy activity* — An activity which represents only an interdependency and does not consume either resources or time.

NOTE — It is sometimes referred to as zero time activity.

d) *Activity-on-arrow network* — The network is a means of representing the interrelationships between the different activities to be performed in a project. The network consists of arrows and nodes where arrow represents activity and nodes represents event. A typical example of an activity-on-arrow network is given in Fig. 6.

e) *Float* — The extent of cushion or flexibility of time available with the activity/activities in the chain by which the activity/activities can be delayed without affecting the completion time of the project.

f) *Critical activity* — An activity with zero float wherein any delay in completion of the activity will delay the completion of project by the same magnitude of time.

g) *Milestone event* — An important or key event in the project denoting a significant stage in the project which may be important for its management such as beginning/completion of significant activities, the events having a pre-set or imposed date, etc.

h) *Interface event* — An interface event is a common event which shows the linkages between activities performed by more than one agencies. It may also denote linkage between activities belonging to two or more sub-projects or two or more projects.

5.1.1 *Recommended Conventions and Symbols*

It is recommended to use conventions and symbols that make logical links more obvious and understandable, and therefore aid in the interpretation of the network. Important symbols and conventions are mentioned in Table 1.

5.2 Recommended Conventions in Drawing the Network

5.2.1 The activity-on-arrow network and its precedence rules have been explained in IS 14580 (Part 1). However, the following specific conventions may be followed in drawing the network.

a) The network may be drawn from left to right starting with the activity(ies) which has no preceding activity in the project, then proceed with drawing of successive activities for which preceding activity has already been drawn.

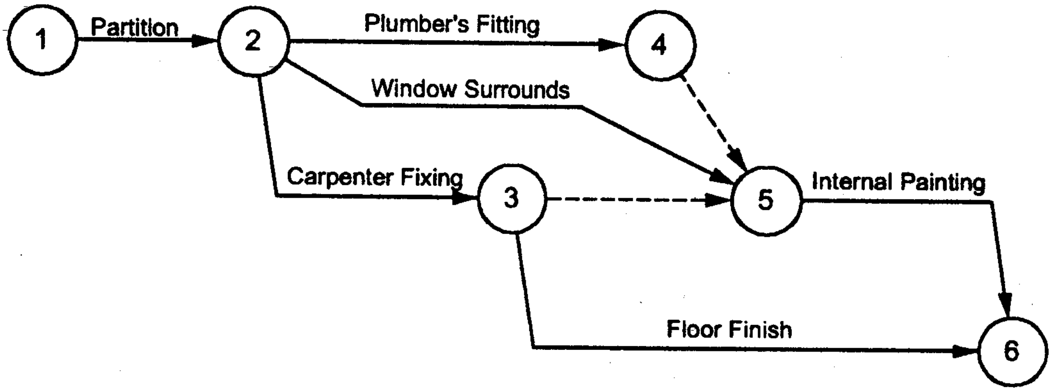
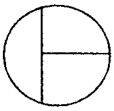
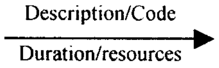
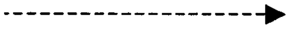
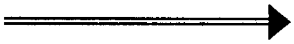
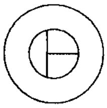
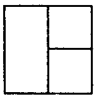


FIG. 6 EXAMPLE OF ACTIVITY-ON-ARROW NETWORK

Table 1 Recommended Symbols for Use on Activity-on-Arrow Network

(*Clause* 5.1.1)

Sl No. (1)	Name (2)	Symbol (3)	Description (4)
i)	Event		The left hand side of the symbol is used for writing the event number. In the right hand side, the earliest event time and the latest event time calculated for the event are written
ii)	Activity		The activity description/code is given above the arrow and duration (and resources, if required) below the arrow. The arrows are normally drawn from left to right
iii)	Dummy Activity		It is shown as dotted arrow and normally drawn from left to right (without description and duration/resources)
iv)	Critical Activity		An arrow with double line/thick line
v)	Interface Event		It is denoted by an additional circle around the symbol denoting the event
vi)	Milestone Event		It is denoted by a square with 3 parts as in the case of other events

b) Arrows imply logical precedence only. Neither the length of the arrow nor its compass direction on the drawing have any significance.

c) The head event of an activity should have higher number than its tail event. This facilitates the analysis during forward pass and backward pass as the forward pass can proceed in ascending order of event number and backward pass in descending order of event numbers.

d) Each activity in the network must have uniquely identified tail event and head event. This implies that there would not be another activity between same pair of tail event and head event.

e) All events in the network should have unique identification number. No two events in the network should have same number. In the initial drawing of the network, sufficient gaps may be given in successive event numbers. This would facilitate addition of new events in proper number sequence, as and when necessary, during subsequent reviews.

f) Every project network should have a uniquely identified starting event denoting the beginning of the project and uniquely identified terminal event denoting the completion of the project.

g) When there are parallel chains of activity and an activity in one chain is also dependent on an activity in other chain, the dependence may be indicated by joining the event in the two chains by Dummy Activity as show in Fig. 7.

Dummy Activity may also be used to avoid multiple activities between the same pair of events.

h) *Restraints and ladders* — In a sequence of activity like the one shown in Fig. 8, it may not be necessary to complete the preceding activity fully before starting the next one.

It may be possible to break each activity into batches and several batches that may be processed in parallel, while the activities in the same batch would follow the sequential order. In such cases, each activity is split into *n* batches (*n* may be 2, 3, 4...), that is, P is broken into P_1 to P_n, S into S_1 to S_n and R into R_1 to R_n where P_1, S_1 and R_1 represent first batch after which next batch of activity could be planned to start for example, after P_1, S_1 could start and similarly after S_1 R_1 could start. Thereafter it is presumed that other batches would be processed in similar manner. However, in the last batch of activities S_n would succeed P_n and R_n would succeed S_n. This is represented by ladder network as shown in Fig. 9.

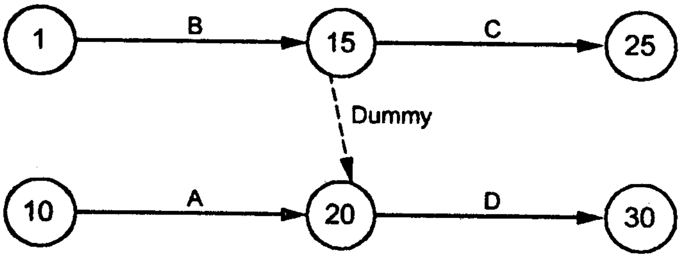


FIG. 7

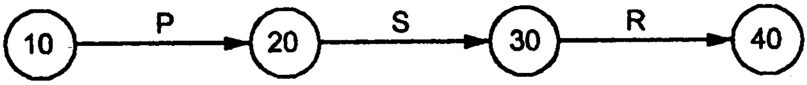


FIG. 8

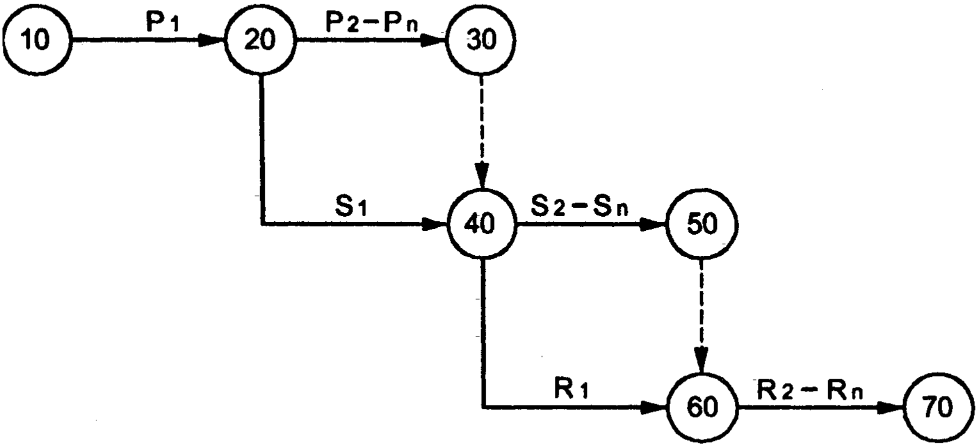
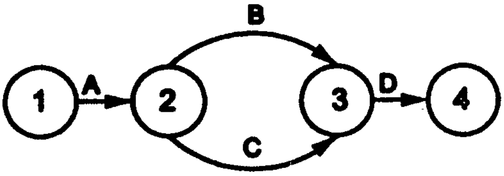


FIG. 9 LADDER NETWORK

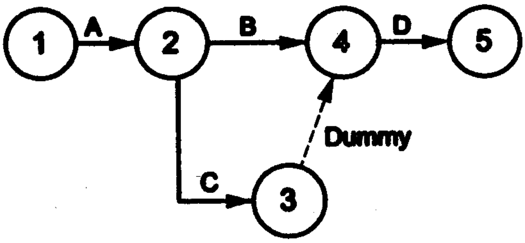
j) Avoid following types of error in drawing network:

1) More than one activity between the same pair of events is prohibited and curves should be avoided. Use dummy activity in such cases.

Incorrect Network

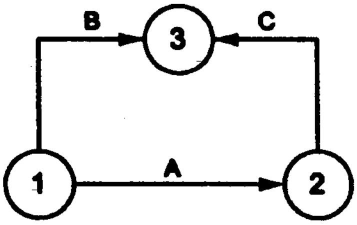


Correct Network

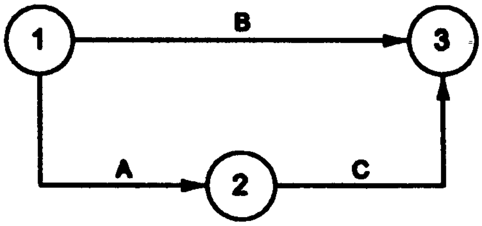


2) Arrows should not move backwards from right to left.

Incorrect Network

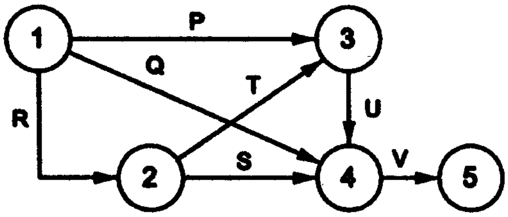


Correct Network

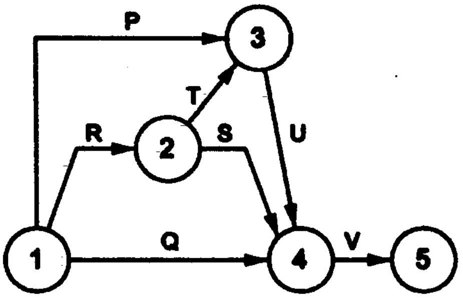


3) Crossing of arrows should be avoided, wherever possible.

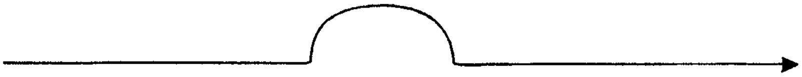
Incorrect Network



Correct Network

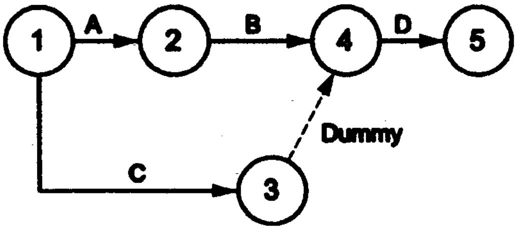


4) Where crossing of arrows is inevitable, it should be shown by the arrow with a kinc at the crossing point.

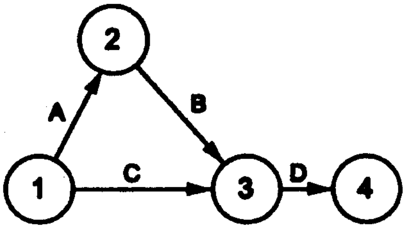


5) Superfluous dummies should be avoided.

Incorrect Network



Correct Network



5.2.2 *Levels of Network*

5.2.2.1 Big projects consisting of large number of tasks are usually broken down into various levels for use at various levels of management in the organization. The top management may like to take a broad overview of the project, while the operating level may be more interested in the detailed tasks to be executed. Usually three levels of networks, denoted by L-I, L-II and L-III are prepared for progress review and monitoring at the highest level, middle level and operating level respectively.

5.2.2.2 The hierarchy of levels is shown in the diagram given in Fig. 10.

An activity at L-I level may compose of an aggregate of a package of activity at L-II level and an activity at L-II level may compose of aggregate of a package of activities at L-III level. Details of individual component activity would appear at L-III or the lowest level of the network.

5.2.2.3 *L-I networks*

L-I networks reflect integration of all contract packages or efforts of all concerned and not only one package or assignment of any specific agency/ department involved in the project implementation. This network represents tasks (in broader terms) required to be undertaken during the project implementation and thus exhibits various tasks, their inter-relationship, time duration (usually in months),

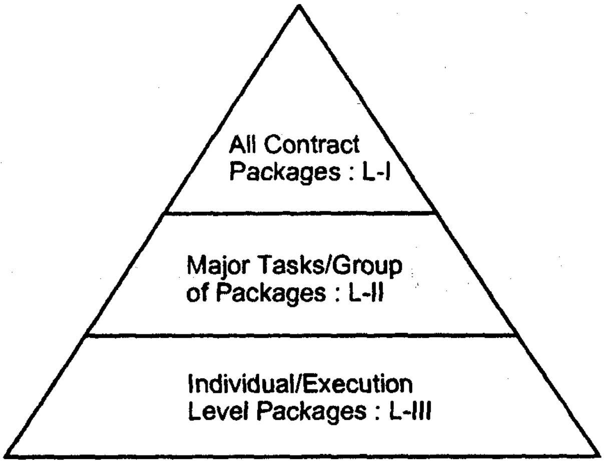


FIG. 10 HIERARCHY OF LEVELS

critical path, milestone event and completion time of the project. This network is primarily used for progress review and monitoring at the highest/board level of the organization. In case of smaller projects, L-I network may not be essential as L-II and L-III may be sufficient for planning, execution and monitoring of project. For a project 'New Plant Construction' requiring completion time of about 2½ years, the L-I network would be useful. The list of tasks/activities, their dependency and time duration of the project 'New Plant Construction' is given in Table 2 as an example and the L-I network drawn on this basis is shown in Fig. 11.

5.2.2.4 *L-II networks*

L-II networks are prepared for a particular package(s) involving majors tasks like, procurement of equipment, their erection, trial runs, commissioning, etc, to be undertaken by different agencies/departments. This network shows the interrelationship of various activities, their time durations (usually in weeks), critical path and completion time. The beginning and the end of L-II network will interface with the beginning and the end of corresponding activity in the L-I network, where it exists. The progress review monitoring and various activities using L-II network is normally within the control of concerned agency/ department responsible for executing the package(s)/ major task(s). L-II networks integrate with L-I networks throughout the execution of the projects. Example of L-II network for new plant construction could be 'Commissioning of certain major equipment', 'Recruitment of employees', 'Fabrication work of plant at site', etc. The list of activities, their dependence, time duration for 'Recruitment of employees' is given in Table 3 as an example and the network drawn on that basis is shown in Fig. 12 which is expected to take 7 months (30 weeks).

5.2.2.5 *L-III networks*

L-III networks are prepared for a specific task to be undertaken by a particular individual or a group. This may involve task like procurement of particular equipment, civil construction of a specific part of a project, erection of an equipment, etc. L-III networks usually contain detailed activities with time duration expressed in days/shifts/hours. The activities of L-III networks contribute towards completion of task(s) reflected in the L-II networks. The beginning and the end of L-III network will interface with the beginning and the end of corresponding activity in the L-II network, where it exists. These networks are usually converted in the form of bar charts for execution and monitoring. An example of L-III network is given in Table 4 which could be 'conduct of activity H' which is expected to take 5 weeks (35 days) (*see* Table 3).

5.3 Guidelines for Drawing a Network

5.3.1 *Work Breakdown Structure and Inter-Relationship Among Activities*

a) The project should be broken down into major work packages. Each work package should be further broken down to contain all the activities required to be performed for its completion;

b) List all the activities to be carried out to complete each work package;

c) Ensure that no activities/tasks required for completion of the work package are excluded. Care should be taken to include the activities like approvals, transmission of information, etc; and

d) Establish the inter-relationship of activities. It is essential that the network logic is developed in consultation with main

Table 2 Example of L-I Network Project: New Plant Construction

(*Clause* 5.2.2.3)

Sl No. (1)	Task/Activity Code (2)	Task/Activity (3)	Dependent on (4)	Duration (Months) (5)
i)	A	Prepare detailed specifications	—	3
ii)	B	Develop plant site	A	5
iii)	C	Complete civil scope drawings	A	2
iv)	D	Prepare fabrication drawings	A	4
v)	E	Prepare specification for imported components	A	4
vi)	F	Purchase imported components	E	10
vii)	G	Recruit personnel	A	7
viii)	H	Train personnel	G	8
ix)	I	Fabricate plant	D	12
x)	J	Procure locally available materials	D	5
xi)	K	Dispatch fabricated plant to site	I	4
xii)	L	Dispatch locally available materials to site	J	3
xiii)	M	Dispatch imported components	F	2
xiv)	N	Erect plant	H, K, L, M & P	6
xv)	O	Conduct trail runs	N	1
xvi)	P	Complete civil work	B & C	7
xvii)	Q	Commission plant	P	—

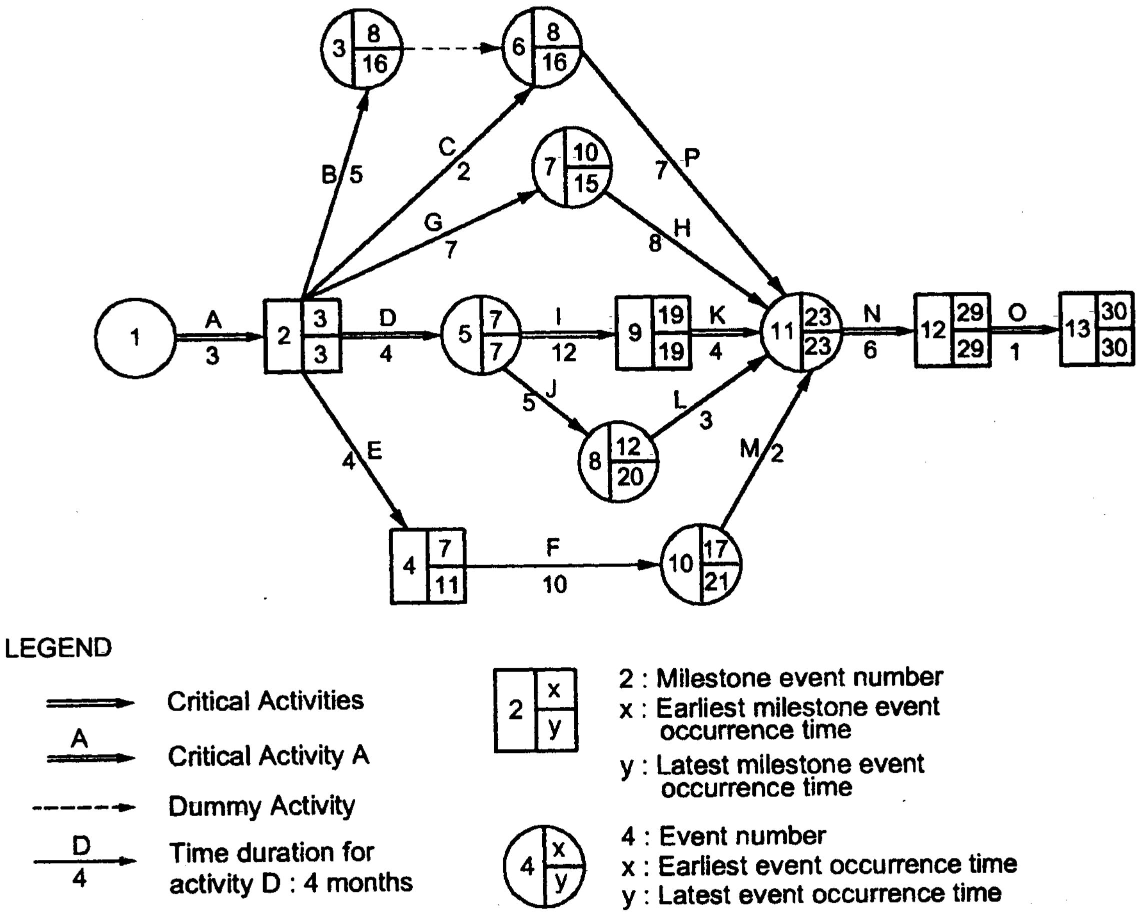


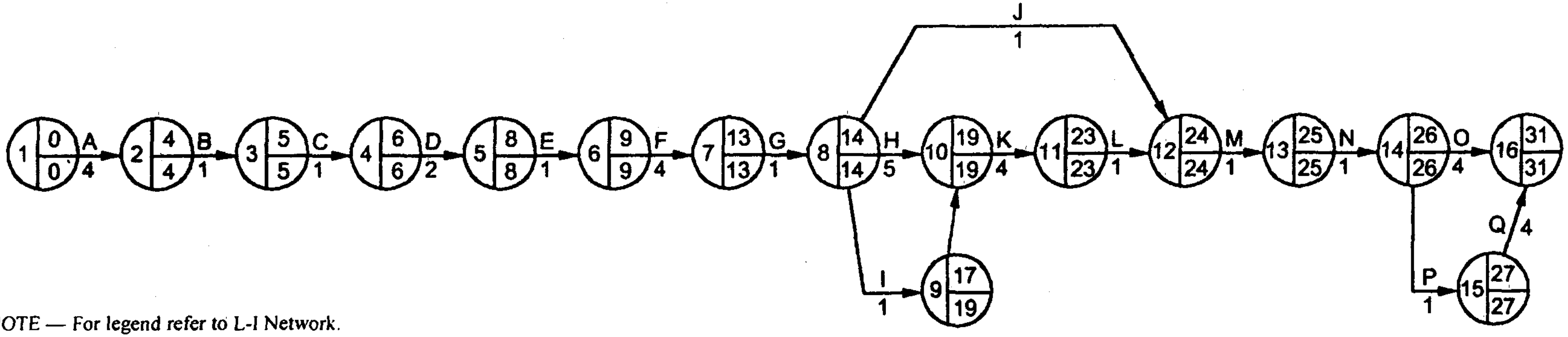
FIG. 11 EXAMPLE OF L-I NETWORK: NEW PLANT CONSTRUCTION

Table 3 Example of L-II Network: Recruitment of Employees

(*Clauses* 5.2.2.4 *and* 5.2.2.5)

Sl No. (1)	Activity Code[1] (2)	Description (3)	Time (Weeks) (4)
i)	A	Manpower assessment	4
ii)	B	Compilation	1
iii)	C	Approval	1
iv)	D	Designing of the advertisement	2
v)	E	Release of the advertisement	1
vi)	F	Receipt of the applications	4
vii)	G	Scrutiny of applications	1
viii)	H	Conduct examination	5
ix)	I	Selection of paper evaluators	3
x)	J	Constitute screening committee	1
xi)	K	Evaluate papers	4
xii)	L	Prepare merit list	1
xiii)	M	Select personnel	1
xiv)	N	Issue appointment letters (P-I)	1
xv)	O	Joining of personnel (P-I)	4
xvi)	P	Issue of appointment letters (P-II)	1
xvii)	Q	Joining of personnel (P-II)	4

[1] Represents sub-activity of G like A, B, C, ...etc.



NOTE — For legend refer to L-I Network.

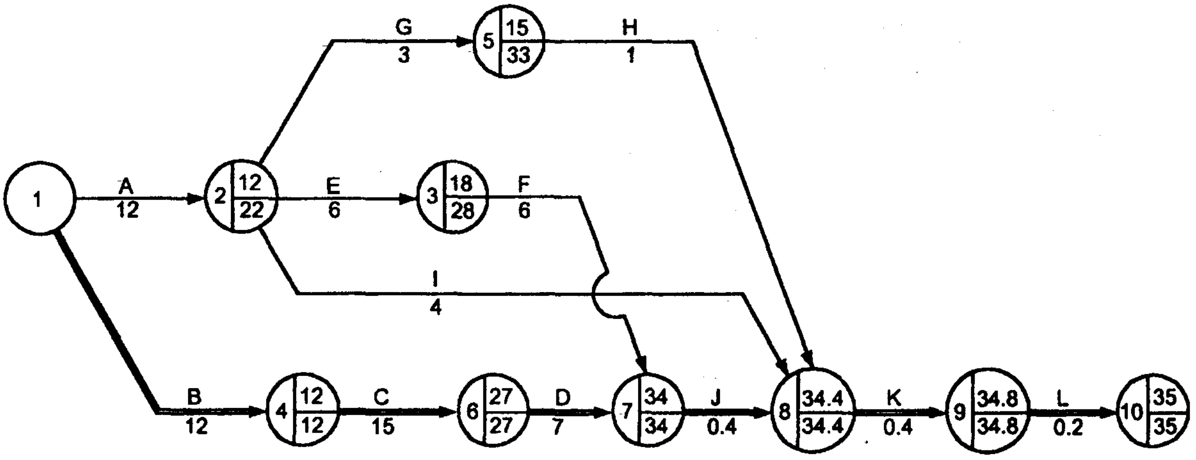
FIG. 12 EXAMPLE OF L-II NETWORK — RECRUITMENT OF EMPLOYEES

Table 4 Example of L-III Network — Conduct of Examination (Refer Activity H of L-II Network)

(*Clause* 5.2.2.5)

Sl No. (1)	Activity Code[1] (2)	Activity Description (3)	Preceding Activities (4)	Duration (Days) (5)
i)	A	Select centres	—	12
ii)	B	Receive papers from paper setters	—	12
iii)	C	Arrange printing of papers	B	15
iv)	D	Dispatch paper to centres	C	7
v)	E	Appoint centre support	A	6
vi)	F	Appoint centre invigilator and other staff	E	6
vii)	G	Finalize seating plan and furniture	A	3
viii)	H	Arrange seats as per plan and put on notice board	G	1
ix)	I	Issue centre tickets to candidates	A	6
x)	J	Check paper parcels, No. of papers subject-wise etc	D	0.4
xi)	K	Distribute papers for writing by candidates	J	0.4
xii)	L	Collect papers, verify and dispatch to evaluators	K	0.2

[1] Represents sub-activity of H.



NOTE — For legend refer to L-I Network.

FIG. 13 EXAMPLE OF L-III NETWORK — CONDUCT OF EXAMINATION

contributors to the project, namely, those involved in the execution of the activities of the project.

5.3.2 *Level of Details of Various Activities*

It is required to be consistent with the level of detail within a network. The level of detail will depend on the following:

a) The project structure and the level of control for example, the time duration of the activities and the frequency of review and updation. It should be noted that the completion of an activity usually implies a change of control, responsibility or supervision;

b) In some cases, an external authority (customer, government department, etc) may impose some activities that will then determine the level of detail for the network;

c) The level of detail should be consistent at each level of management and reflect the scope of direct control at each level; and

d) Include details (of the appropriate level) relevant to the uses for which the network is prepared like communication, coordination, supervision, etc.

5.3.3 *Method for Drawing Network*

a) List all the activities which do not have any pre-condition or preceding activities;
b) Draw all these activities in parallel from the starting node;
c) After this, draw the activities which are following the project activities already drawn and are dependent on the completion of those activities;
d) Find out any external activity(ies) or condition(s) that might govern the start of these activities; and
e) Proceed to the subsequent activities in the same manner throughout the network.

It is essential that the network logic is developed in consultation with the main contributors to the project, namely those involved in the execution of the project.

5.3.4 *Important Points to Remember for Drawing the Network*

a) As far as possible, avoid activity arrows crossing each other in order to assist legibility;
b) Make every activity arrow (or a horizontal part of it) long enough to carry any additional text;
c) Separate parallel activity arrows sufficiently to ensure that their texts cannot be confused with each other. If possible, the spacing should be sufficient to facilitate any subsequent logic changes;
d) It is helpful to allocate temporary event numbers during the development of a network to facilitate any subsequent changes;
e) Make the longest chain of arrows, the centreline of the drawing sheet and space events equally along this line;
f) Add other chains of activities, working outwards from the centre. It may be necessary to re-draw parts of the network to reduce crossovers; and
g) To enable easy reading of the network the following points may be helpful:
    1) Those parts of the activity lines not parallel to the base line should, wherever possible, be kept at a constant angle but not vertical;
    2) Keep a consistent vertical spacing between activity lines (a minimum spacing of not less than 25 mm is recommended); and
    3) Where dummies have to cross several lines, vertical lines angled at top and bottom may be used.

5.3.5 *Numbering the Events*

a) For numbering the events start from left to right and top to bottom direction of the network;
b) When numbering the events initially, it is recommended to use the number in the multiple of 10 that is 10, 20, 30 to facilitate adding more events subsequently without altering the numbers of existing events;
c) The event which does not have any preceding event(s) should be considered as the starting event(s) and should be numbered first;
d) All the succeeding events to the above mentioned events be numbered thereafter in the same manner; and
e) Same procedure should be adopted for all events.

5.3.6 *Formal Network Preparation*

When a satisfactory plan has been established, it is desirable to produce a formal copy of the network that is easily readable and therefore, readily acceptable to management. Formal copies are also needed for record purposes. These can be either manual or computer generated.

5.3.7 *Considerations for the General Layout of the Network*

5.3.7.1 If the number of activities is large, it is preferable to use several sheets of reasonable size rather than one very large sheet. If more than one sheet is needed, it is more important to subdivide a project into meaningful and convenient modules or sub-networks describing a work package.

5.3.7.2 The activities of each department can be arranged to lie in a broad horizontal band across the drawing sheet. This can be useful, particularly when communicating with people not used to networking, but it has the disadvantage that it generally makes poor use of the space available on the drawing sheet, and may result in long links running across the network from top to bottom.

5.3.7.3 In networks drawn on time scale called squared network as also defined in IS 14580 (Part 1), the activity arrows are drawn horizontally with a length proportional to their duration according to the time scale marked horizontally across the sheet. An advantage of such networks is that re-planning, needed as the result of slippages, is made more obvious pictorially. 'Review Point' can be represented by a vertical movable markers or cursor. Such networks can be useful control tools in some circumstances, including the following:

a) Manually calculated networks of small projects (normally limited to about 200 activities);
b) Self-contained networks of small sub-projects (normally limited to about 200 activities), such as for use by a foreman on a building site; and
c) Prepared for higher-level management control.

6 SQUARED NETWORK

6.1 While bar charts are useful as a means of graphical display of project activities on a time scale, it is difficult to establish the exact inter-relationship between activities as well as the float available to the activities. Improved methods such as network based on activity-on-arrow or activity-on-node are able to show the inter-relationship between activities as well as expected completion time of the project, but these methods are also not able to show the float available to different activities, which not only provides information regarding the delay, which could be allowed in the completion of the activity without affecting the completion time of the project but could be very useful for optimal utilization of resources. To overcome these deficiencies, network diagram with time scale, also called squared network, are used.

6.2 Procedure for Drawing Squared Network

a) A network showing the inter-relationship of various activities involved in the project is drawn with their time duration and the project completion time is determined using critical path method.
b) Depending upon the project completion time, suitable time scale should be considered and plotted on the x-axis.
c) The various critical activities of the critical path are drawn to scale with a demarcation sign at the end of each activity to indicate the completion and start of the next activities.
d) Thereafter other activities to scale, considering their dependency or their possible start, are drawn. If two or more activities could start after an activity, the activity with lower time duration should be drawn first and near to the critical path, followed by other activities, but all the activities are drawn parallel to the critical path according to their sequence till all the activities are covered. No inclined line (activity) should be drawn.
e) The lines representing the activities are drawn to scale and parallel to the critical path with firm line, the extra time available to the activity, depending on the dependency consideration is shown by dotted lines (---). The lines depicting the relationship between the activities should be drawn perpendicular with respect to path. Event numbers may also be shown on the squared network to establish linkages with activity-on-arrow network.
f) After the complete time scaled diagram called squared network has been drawn, the time scale may be replaced with calendar dates according to the project calendar for more effective utilization.

6.3 Some illustrative examples of squared network drawn from activity-on-arrow network are given in Fig. 14A, 14B, 15A and 15B.

Example shown above explains the drawing of squared network, float available with the activities as well as the calendar dates. The duration of the project shown in the above network is 10 days. Before changing to calendar dates, a time scale with suitable time unit as a day shown above has been drawn. Assuming 6 days working in a week and the project commencement on 22 January (Monday), the calendar shows the actual dates on which the different activities have been planned, which excludes 26 January and 28 January, being holidays.

Assuming the project is planned to commence on 1 January, the activity-on-arrow network, squared network as well as the calendar schedule of the project is shown below. Project calendar assumes 6 days working per week and 26 January as national holiday.

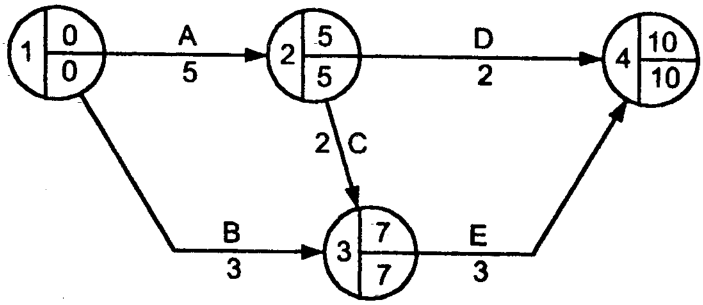
6.4 Some Potential Advantages of Squared Network

a) Squared network enables understanding of the float as well as the inter-relationship with various activities, which could be utilized for resource levelling leading to optimal utilization of resources;
b) Adoption of the squared network to calendar dates would help in effective planning, execution and monitoring of the project; and
c) It provides understanding that the delay in the completion of the activity to the extent of float available would not affect the project completion time.

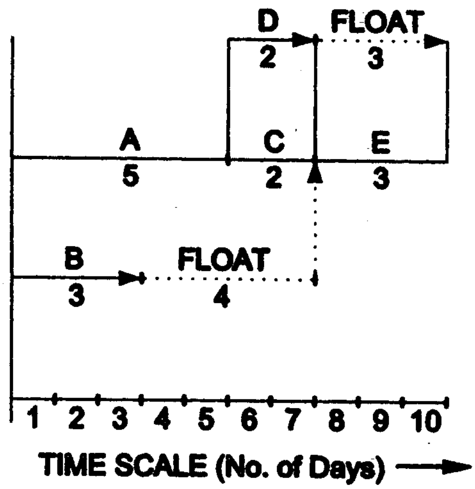
7 PRECEDENCE NETWORK

Activity-on-node or precedence networks are prepared as an alternative to arrow diagram. In

Example I



14A Network: Activity-on-Arrow

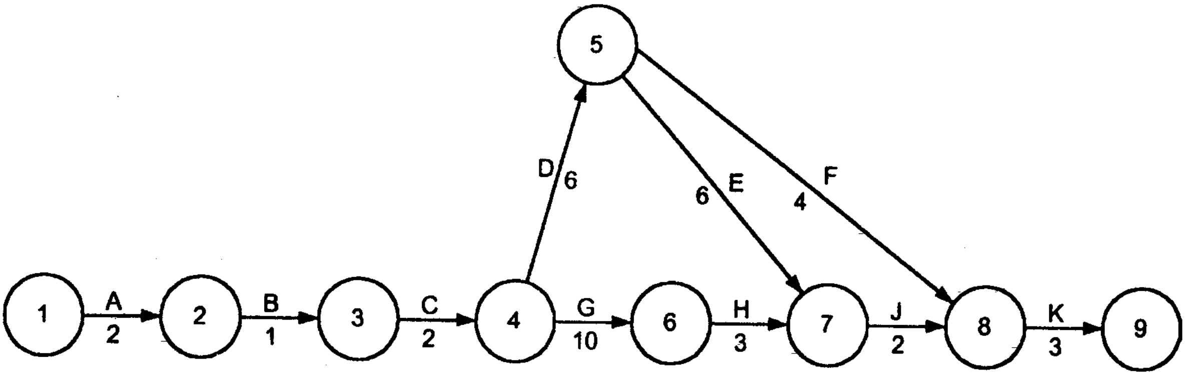


CALENDER DATE	22	23	24	25	27	29	30	31	1	2
	January								Feb	

14B Squared Network

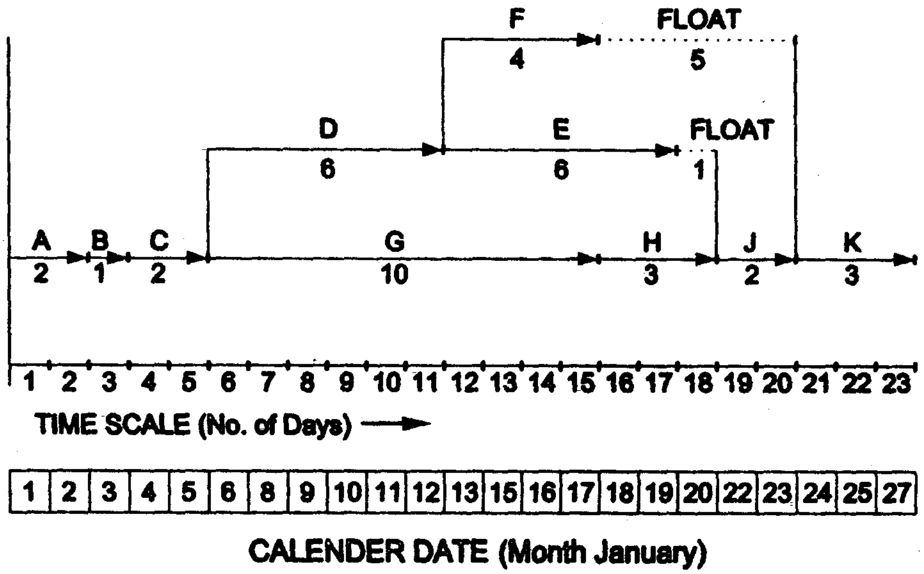
FIG. 14 SOME ILLUSTRATIVE EXAMPLES OF SQUARED NETWORK DRAWN FROM ACTIVITY-ON-ARROW NETWORK

Example II



15A Network: Activity-on-Arrow

FIG. 15 SOME ILLUSTRATIVE EXAMPLES OF SQUARED NETWORK DRAWN FROM ACTIVITY-ON-ARROW NETWORK — *Continued*



15B Squared Network

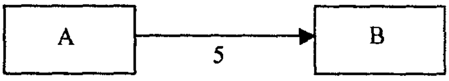
FIG. 15 SOME ILLUSTRATIVE EXAMPLES OF SQUARED NETWORK DRAWN FROM ACTIVITY-ON-ARROW NETWORK

activity-on-node network introduction of dummy are not required. It is suitable for computer programming enabling time, resource and cost analysis. With the preparation of networks using work-breakdown-structure it is only logical to refer the network by events. In this form of network, the activities are shown in the nodes and the arrows show logical precedence as shown in Fig. 16.

7.1 The logic relationship and precedence diagram is shown involving lead and lag elements in the following manner:

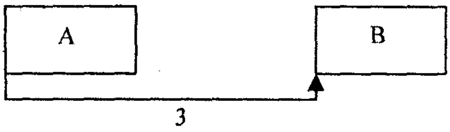
1. FINISH TO START RELATIONSHIP

   Start of B must lag 5 days after the finish of A.



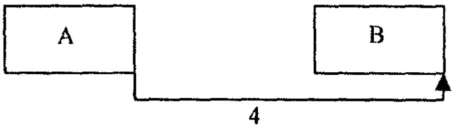
2. START TO START RELATIONSHIP

   Start of B must lag 3 days after the start of A.



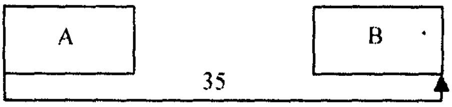
3. FINISH TO FINISH RELATIONSHIP

   Finish of B must lag 4 days after the finish of A.



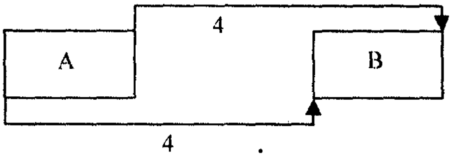
4. START TO FINISH RELATIONSHIP

   Finish of B must lag 35 days after the start of A.



5. COMPOSITE START TO START AND FINISH TO FINISH RELATIONSHIP

   Start of B must lag 4 days after the start of A and the finish of B must lag 4 days after the finish of A.



7.2 As an illustration a small project of laying pipe sections is undertaken as given in Table 5. The problem is converted into the network form by both the methods of network preparation, namely activity-on-arrow as shown in Fig. 17 and activity-on-node as shown in Fig. 18.

8 HISTOGRAM

8.1 Out of several methods of presenting a frequency distribution graphically, histogram is the most popular and widely used. A histogram is a set of vertical bars whose areas are proportional to the frequencies represented.

8.2 To construct a histogram we must have data in the form of a frequency distribution. The independent

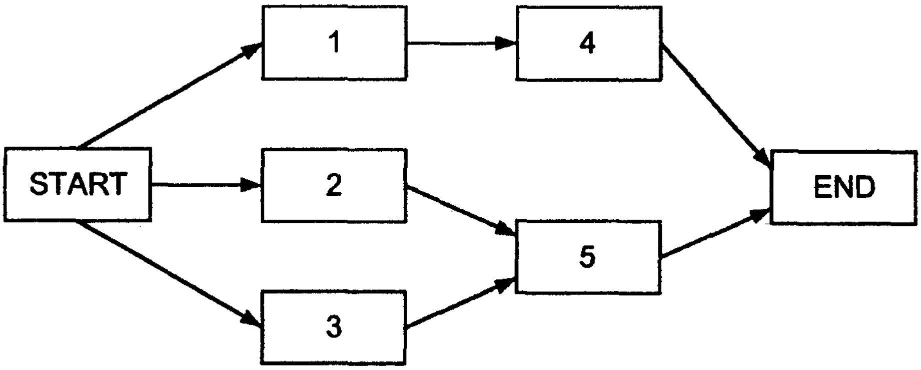


FIG. 16 PRECEDENCE NETWORK

Table 5 Activities for Pipe Project
(*Clause* 7.2)

Sl No. (1)	Activity Number (2)	Activity Description (3)	Succeeding Activities (4)	Duration (Months) (5)
i)	1	Project start	2, 3	1
ii)	2	Relocate telephone cable	10	4
iii)	3	Excavate	4	2
iv)	4	Install pipe section 1	5, 6	4
v)	5	Backfill section 1	7	1
vi)	6	Install pipe section 2	7, 8	6
vii)	7	Backfill section 2	9	2
viii)	8	Test pipe section	9, 10	2
ix)	9	Compaction	12	2
x)	10	Install manhole	11	3
xi)	11	Test relocated telephone line	12	2
xii)	12	*Final testing*	—	1

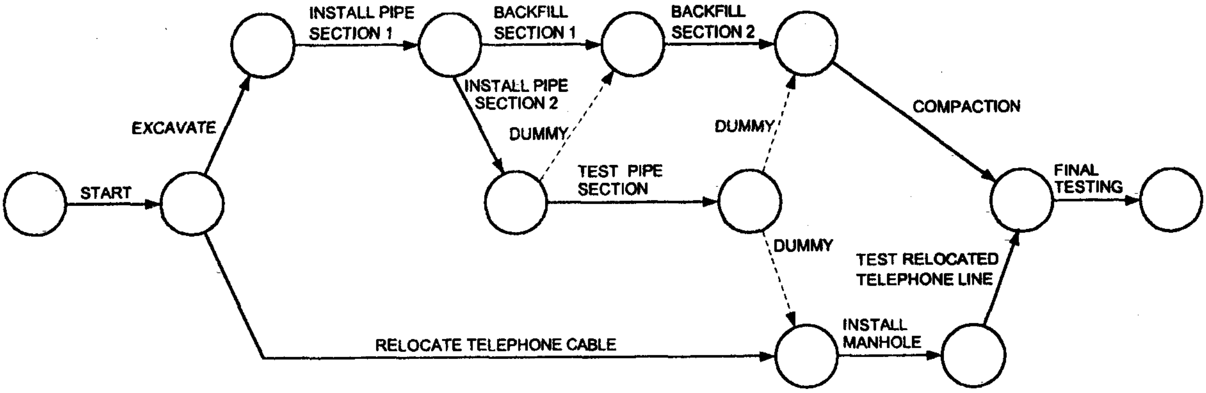
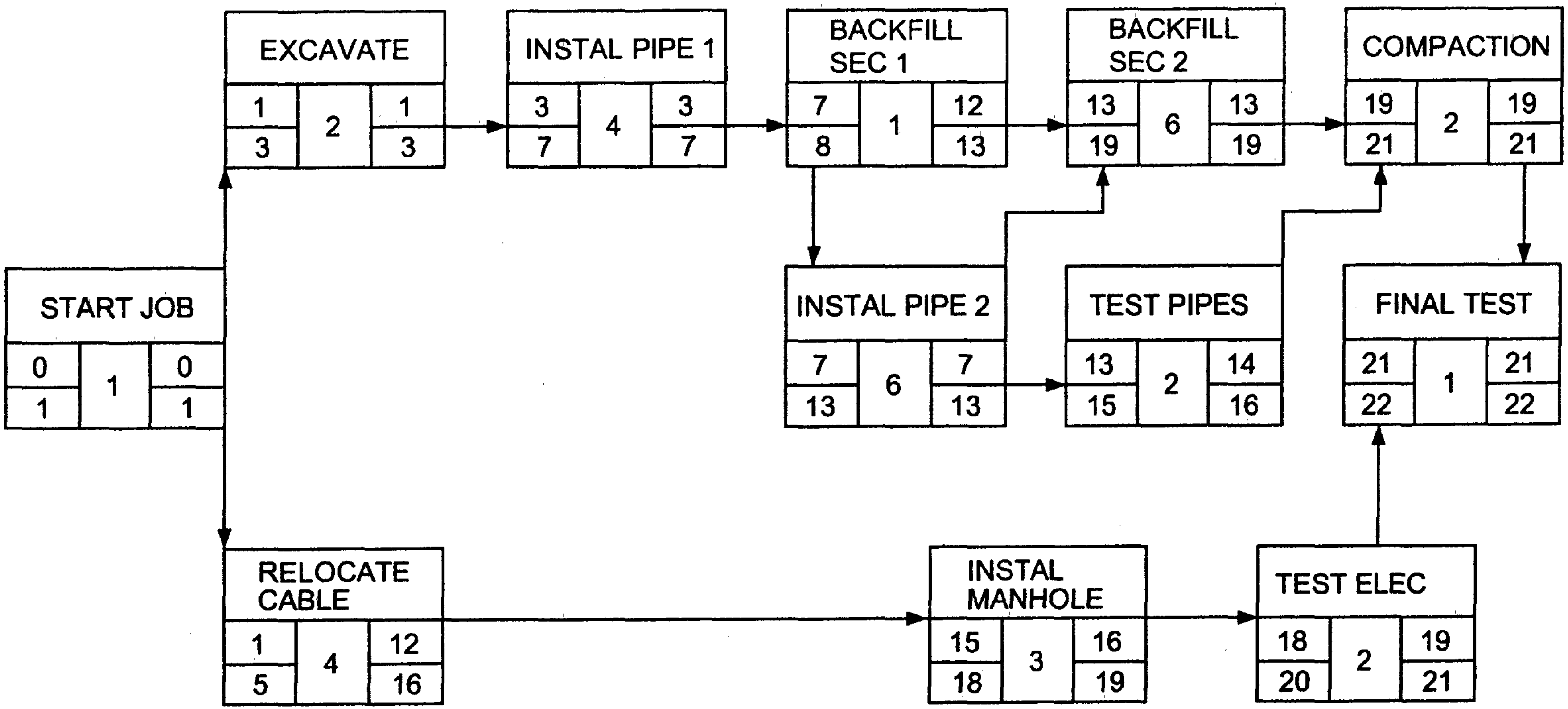


FIG. 17 PIPE PROJECT: ACTIVITY-ON-ARROW NETWORK



Note : The above notations are depicted as

Description		
Earliest Start (T_E)	Duration	Latest Start (T_L)
Earliest Finish (T_E)		Latest Finish (T_L)

FIG. 18 PIPE PROJECT: ACTIVITY-ON-NODE/PRECEDENCE NETWORK

variable is always taken on the x-axis and the frequencies depending on it on the y-axis. Each class is then represented by a width on the scale that is proportional to its class-interval. The width for each rectangle on the x-axis shall remain the same in case the class-intervals are uniform throughout. If they are different, the width of the rectangles shall vary proportionately. The y-axis represents the frequencies of each class which constitute the height/length of its rectangle. In this manner we get a series of rectangles each having a class-interval as its width and the frequency as its height/length. The area of the histogram represents the total frequency as distributed throughout the classes. The histogram should be clearly distinguished from a bar diagram. The distinction lies in the fact that whereas a bar diagram is one-dimensional, that is, only the length of the bar is significant and not the width, a histogram is two-dimensional, that is, in a histogram both the length as well as the width are significant. In case of unequal class-intervals suitable adjustments are required to be made in frequencies. However, a histogram cannot be constructed with open-end class(es).

8.3 The technique of constructing a histogram is given below for:

a) distributions having equal class-intervals; and
b) distributions having unequal class-intervals.

8.3.1 *Distributions Having Equal Class-Intervals*

When class-intervals are equal, take the independent variable on the and its frequencies on the y-axis and construct adjacent rectangles. In such a case the height/length of each rectangle will be proportional to its frequency.

8.3.1.1 For example, in a water treatment plant, the histogram for the data given in Table 6 regarding Chlorine level in samples of treated water with 0.3 ppm class-intervals is shown in Fig. 19.

Table 6 Data for Chlorine Level in Samples of Treated Water

Sl No. (1)	Class (2)	Frequency (3)
i)	15.2 - 15.5	2
ii)	15.5 - 15.8	5
iii)	15.8 - 16.1	11
iv)	16.1 - 16.4	6
v)	16.4 - 16.7	3
vi)	16.7 - 17.0	3

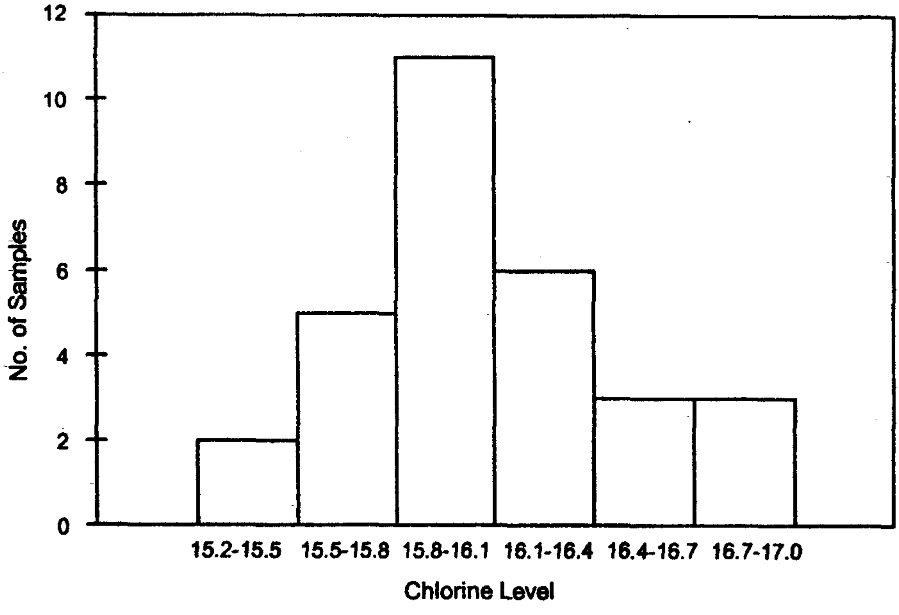


FIG. 19 HISTOGRAM

8.3.2 *Distributions Having Unequal Class-Intervals*

When class-intervals are unequal, an adjustment for unequal class-intervals must be made. The adjustment consists of finding for each class the frequency density. The frequency density is the frequency for that class divided by the width of that class. Frequency density histogram constructed from these density values would have the same general appearance as the graphical representation developed from equal class-interval.

For making the adjustment we take that class which has lowest class-interval and adjust the frequencies of other classes. For example, if one class-interval is twice as wide as the one having the lowest class-interval, divide the height of its rectangle by two; if it is three time more, divide the height of its rectangle by three; etc, that is, the heights will be proportional to the ratio of the frequencies to the width of the classes or frequency densities.

8.3.2.1 The class-intervals of hourly wages in a factory and number of workers falling in each class is given in Table 7.

Since the class-intervals are unequal, frequencies must be adjusted. In this case, the lowest class-interval being Rs. 5, the frequency of the class 30-40 shall be divided by 2 since the class interval is double and that of class 40-60 by 4 since class-interval is 4 times the lowest class-interval, etc. Frequency density histogram with these adjustments is depicted in Fig. 20.

Table 7 Data for Hourly-Wages to Factory Workers

Sl No. (1)	Hourly Wages (in Rs.) (Class) (2)	Number of Workers (Frequency) (3)
i)	10-15	7
ii)	15-20	19
iii)	20-25	27
iv)	25-30	15
v)	30-40	12
vi)	40-60	12
vii)	60-80	8

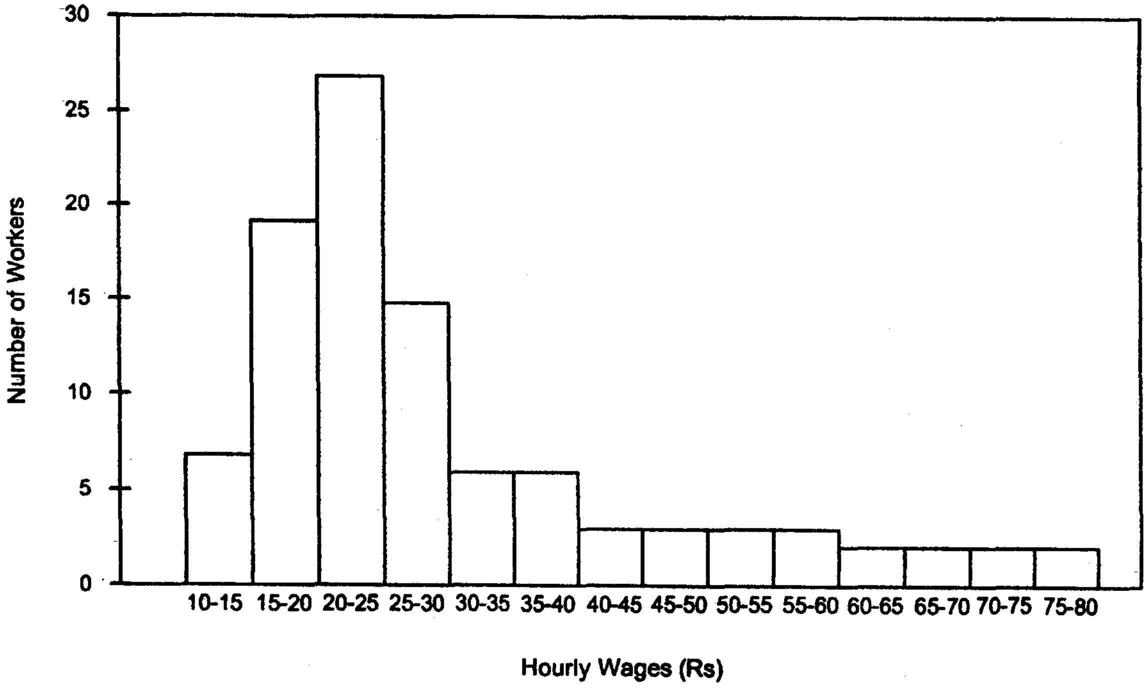


FIG. 20 HISTOGRAM

In project management, the histogram can be used for varieties of applications like resource allocation, utilization and levelling, cost allocation, etc.

Figure 21 shows the histogram depicting the requirement of detailers, being a critical resource in this case, for the completion of tasks scheduled as per the accompanying bar chart. This example is related to an engineering department in which the activities/skills can be broken down into layout engineering, detailing and checking. Figure 21 shows an attempt to calculate the workload requirements created by twenty-two different tasks labelled *A* to *V*. The histogram shows uneven requirement of detailers. An attempt could be made to reschedule the tasks to achieve a more levelled requirement of detailers. This rescheduling of tasks may lead to re-allocation of other resources and eventually the tasks may have to be adjusted for ensuring overall optimal utilization of resources within the time frame.

9 TIME VARIANCE CHARTS

9.1 In project management we typically monitor specific characteristics of a project as the work progresses, namely performance level, costs, and time schedules. The three major reasons for putting controls in place are to track progress, detect deviation from plan, and take corrective action.

9.2 The time variance chart depicts the actual achievements as against the planned targets and the difference between the two. Larger values of these differences indicate significant departure from plan. Typical variance charts are snapshots in time (the current period) of the status of the entity being tracked. It is a tool used by project managers to monitor progress against the time factor. These charts can be prepared for entire project, work package, even for an activity or a milestone event.

9.3 For preparing time variance chart for a project/work package consisting of a large number of activities, the progress of each activity and its impact on completion time should be the guiding factor for preparing the time variance chart. The aggregate progress could be assessed by assigning weightage to each activity.

9.4 If the actual progress of work during a fixed period of time has been less than the planned output, then a 'Time over run' condition can be said to exist. However, if the actual progress of work during a fixed period is more than the planned progress, then a 'Time under run' condition exists. The 'Time under run' and 'Time over run' condition are graphically depicted in Fig. 22.

9.5 Time Variance Slip Chart

9.5.1 Time variance slip chart is another kind of chart which in one form or another may be used to present information on time variance. The slip chart has to be relatively simple with proportionately long duration activities to be of some value when drawn to a time scale.

9.5.2 Time variance slip charts are usually summaries or components of the more detailed networks and these, if small enough, are often conveniently drawn to a time scale and highlight key events. These charts can give an overview of the project in a form suitable for senior management. Further, it may be combined with slippage curves for the key events to show how their dates have changed over the previous two reviews. Such charts should be supported by documentation, which gives the reasons for the changes. An example for selected key events of the project with their planned date, revised date alongwith the slippages is given in Table 8 and its corresponding chart is given in Fig. 23.

10 COST VARIANCE CHART

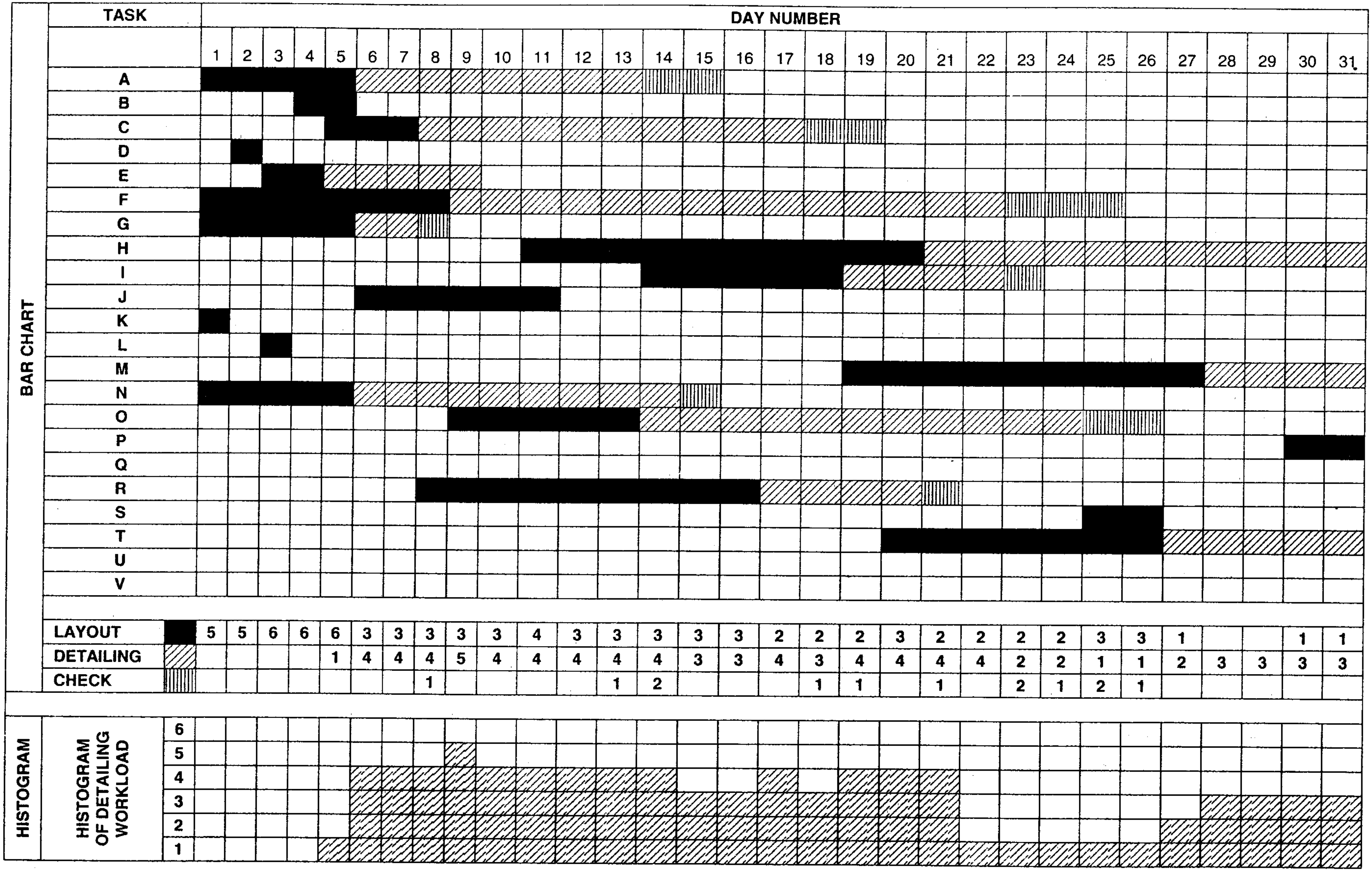
10.1 The cost variance chart is used for control of costs related with work performance and time schedule aspects. The terminology used for specific type of analyzed information, namely periodical, cumulative and projected, which are required for the preparation and use of these charts is defined as under:

a) *BCWS (Budgeted cost of work scheduled)* — It is the budgeted cost of work (at a predetermined price) scheduled to be completed during and cumulatively upto the end of a given period.

b) *BCWP (Budgeted cost of work performed)* — It is the budgeted cost of work actually performed during and cumulatively upto the end of a given period of time. It is also known as 'Earned Value' of actual work.

c) *ACWP (Actual cost of work performed)* — It is the amount of actual cost incurred for work (at actual price) performed during and cumulatively upto the end of a given period.

d) *EAC (Estimated cost at completion)* — It is the total cost estimated for the completion of the project. It is arrived at by adding cumulative actual cost of work performed upto a given time to the projected cost for remaining work.



TASK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
A	■	■	■	■	■	▨	▨	▨	▨	▨	▨	▨	▨	▥	▥																
B				■	■																										
C					■	■	■	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▥	▥												
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M																			■	■	■	■	■	■	■	■	■	▨	▨	▨	▨
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P																														■	■
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S																									■	■					
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U																															
V																															

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
LAYOUT	■	5	5	6	6	6	3	3	3	3	3	4	3	3	3	3	3	2	2	2	3	2	2	2	2	3	3	1			1	1
DETAILING	▨					1	4	4	4	5	4	4	4	4	4	3	3	4	3	4	4	4	4	2	2	1	1	2	3	3	3	3
CHECK	▥								1					1	2				1	1		1		2	1	2	1					

FIG. 21 HISTOGRAM SHOWING REQUIREMENT OF DETAILERS FOR A SET OF 22 TASKS AS PER THE TIME SCHEDULE INDICATED BY BAR CHART

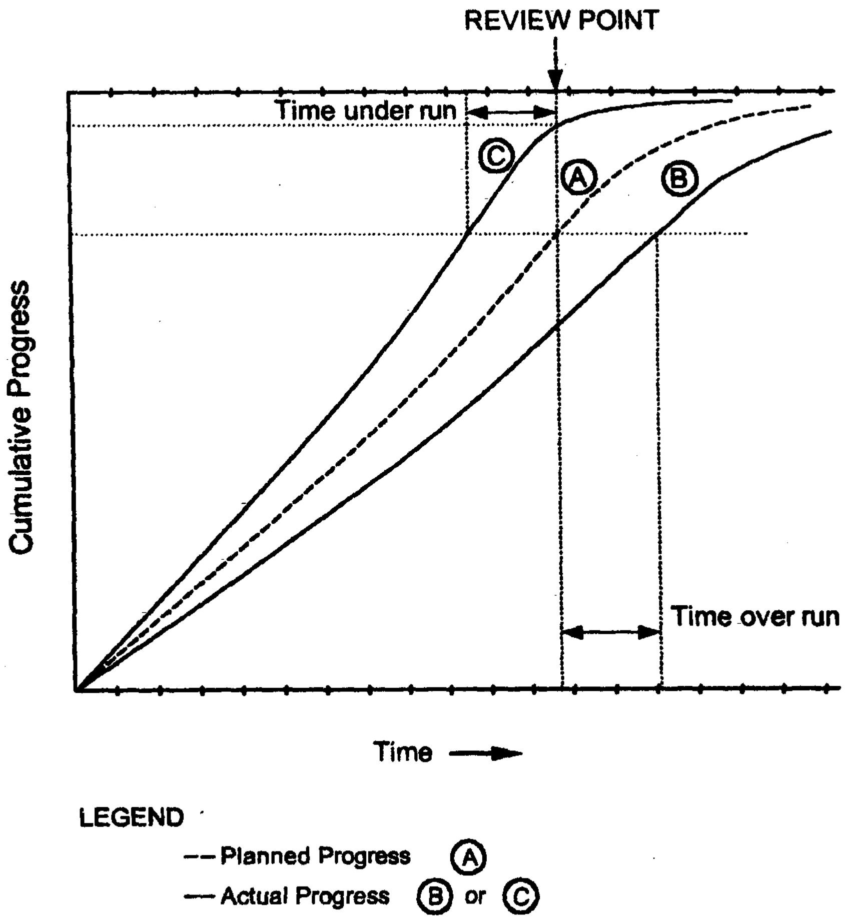

FIG. 22 EXAMPLE OF TIME VARIANCE CHART

Table 8 Data for Selected Key Events of the Project Giving Slippages

(*Clause* 9.5.2)

Sl No. (1)	Key Event Number (2)	Reasons for Slippage (3)	Original Planned Date (4)	Current Planned Date (5)	Slip (in Time Periods, in Weeks) (6)
i)	1	Delayed site handover	25 January	8 February	2 weeks
ii)	3	Heavy traffic/road closure	14 February	20 March	5 weeks
iii)	5	Delayed receipt of equipment	2 April	9 May	5 weeks
iv)	7	Change in specification	18 May	10 August	11 weeks
v)	9	Shortage of manpower	13 September	11 October	4 weeks

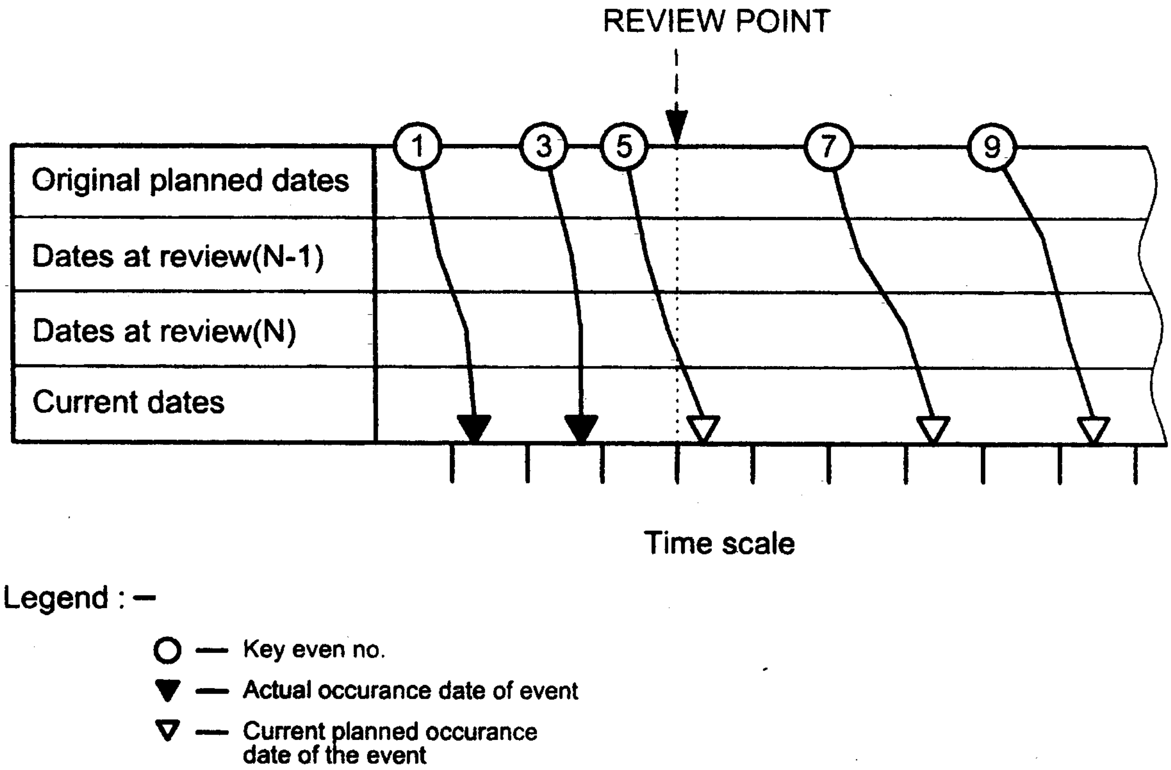

FIG. 23 EXAMPLES OF TIME VARIANCE SLIP CHARTS

10.2 The cost variance charts used for controlling costs related with work performance and time schedules are:

a) Project cost and schedule progress (*see* Fig. 24), and

b) Projected cost and schedule overrun (*see* Fig. 25).

10.3 Drawing the Cost Variance Charts

10.3.1 The above-mentioned information is plotted in the form of line charts shown in Fig. 24 and Fig. 25. The charts have, however, to be designed according to the type and size of the product and the project, information system followed, purpose of use and needs of the user.

10.3.2 In Fig. 24, time is shown on the x-axis and cost is shown on the y-axis. The information on BCWS, BCWP and ACWP are plotted periodically and cumulatively in the form of line graphs. A vertical line parallel to the y-axis relating to the report date starting from x-axis is drawn cutting through the BCWS, BCWP and ACWP lines. The portion of this vertical line (dotted) in the chart joining the BCWP line and ACWP line indicates the cost variance (CV). Where this vertical line joins the BCWP graph and BCWS graph indicates schedule variance (SV) contributing to cost variance. Where this graph cuts the BCWS and ACWP graphs it indicates accounting variance (AV) contributing to cost variance, due to price changes.

10.3.3 In the chart in Fig. 25, time is indicated on the x-axis and the cost is shown on the y-axis. The cumulative graph of BCWS and BCWP and ACWP and the report date line (dotted) as drawn in Fig. 24. The chart can be used for estimating the time and cost requirement of the remaining work on the basis of experience gained till date. The work remaining to be performed and the estimated cost of the balance work is added to the ACWP on the date of review, to arrive at the estimated cost to completion (EAC). Based on the BCWS line for the remaining work and superimposing it on ACWP line on the review point, we can draw the projected ACWP line. The point at which projected ACWP line intersects the EAC line determines the projected completion date of the project and the projected scheduled delay. The Fig. 25 in this chart is used for displaying cost/schedule inter-related progress information.

10.4 Use of Cost Variance Charts

The information that could be derived from these charts for management use is the integrated cost control which principally relates to cost variance schedule variance and accounting variance. Their details are given as under.

10.4.1 *Cost Variance*

It is the difference between the budgeted cost of work performed and the actual cost of work performed:

Cost variance (CV) = BCWP – ACWP

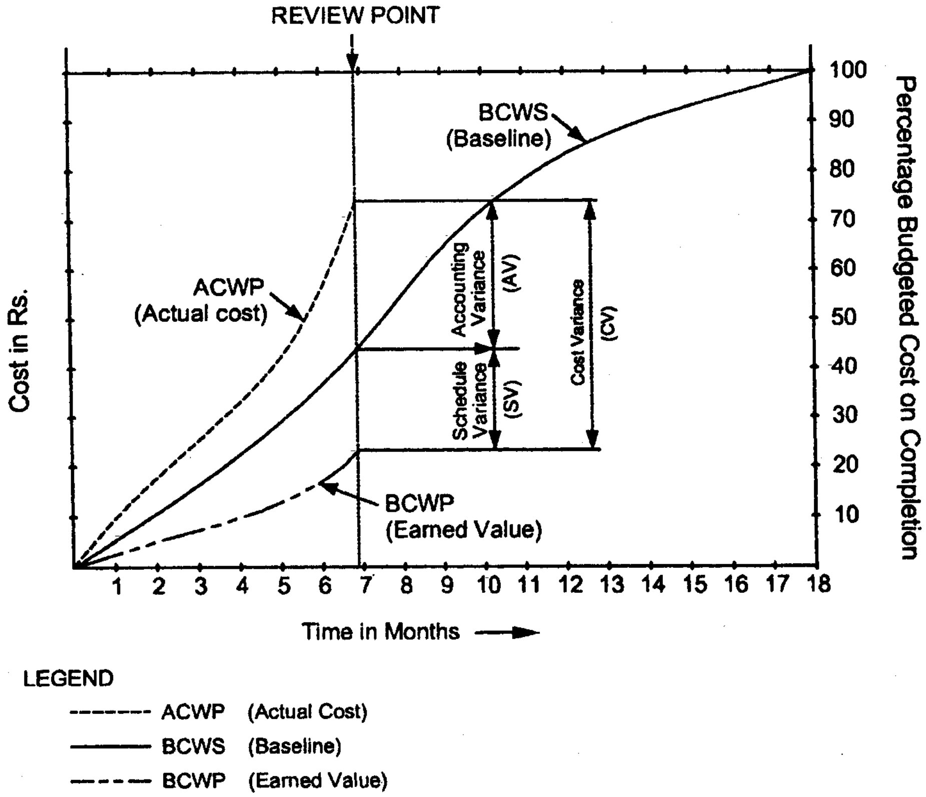

FIG. 24 PROJECT COST AND SCHEDULE PROGRESS

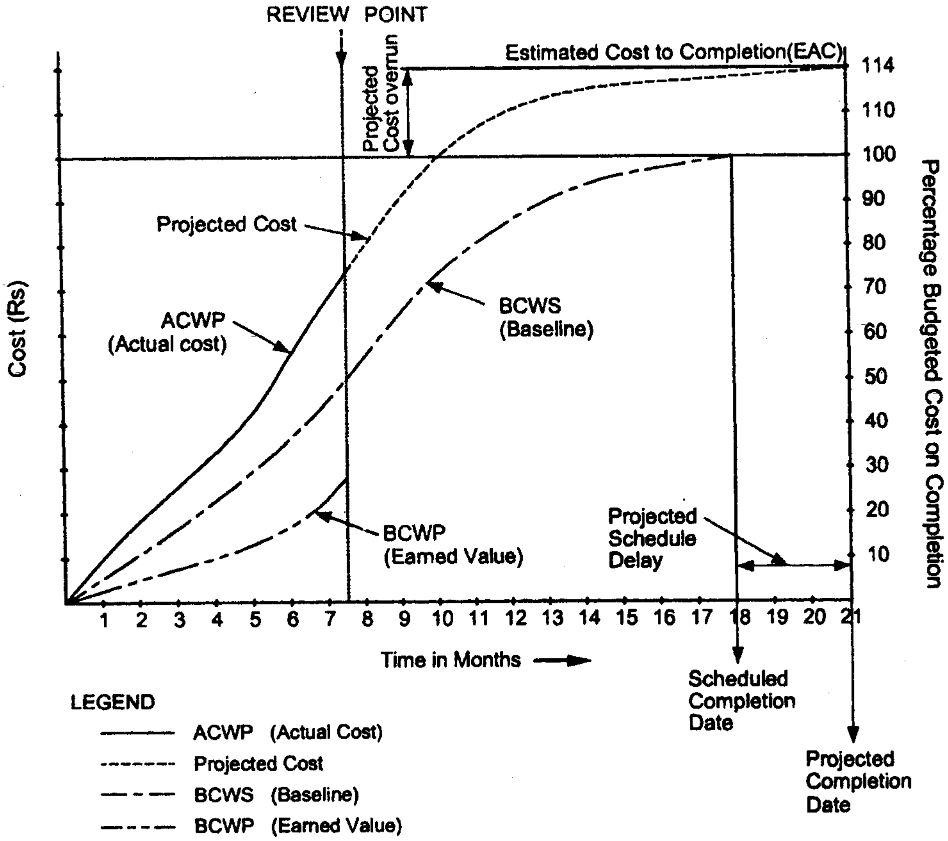

FIG. 25 PROJECTED COST AND SCHEDULE OVERRUN

When CV is equal to zero, the project is on cost. When it is negative, there is cost overrun and when it is positive, there is cost underrun.

Cost variance can be due to various reasons. The two components of cost variance are schedule variance (SV) and accounting variance (AV):

$$\text{Cost variance, percent (CVP)} = \frac{\text{CV}}{\text{BCWP}} \times 100$$

10.4.2 *Schedule Variance*

It is difference between the budgeted cost of work performed and the budgeted cost of work scheduled. It is the component of the cost variance which is attributed to schedule slippage.

$$\text{SV} = \text{BCWP} - \text{BCWS}$$

When SV is equal to zero, the project is on schedule. When it is negative, the project is behind schedule and when it is positive, the project is ahead of schedule.

10.4.3 *Accounting Variance*

It is the difference between the budgeted cost of work scheduled and actual cost of actual work performed. It is the component of cost variance which is attributed to reasons other than schedule slippage.

$$\text{Accounting variance (AV)} = \text{BCWS} - \text{ACWP}$$

When AV is equal to zero, the project is on budget. When it is negative, the project is over budget and when it is positive, the project is under budget.

10.5 Benefits of Cost Variance Charts

10.5.1 The charts provide vivid and visually understandable, analyzed and integrated information for cost control. With proper network, work packages, cost centres and cost allocation, the charts are useful in highlighting planned and actual cost trends to facilitate comparisons, identify variances, make realistic projections, probe into problem areas and formulate corrective action.

11 RESOURCE UTILIZATION AND PRODUCTIVITY CHART

11.1 The network techniques are used for integrated planning and control of the four inter-related aspects of work, time, resource and cost of a project. Each resource has its specific characteristic and is directly related to scope and time schedule of work. The management of resources generally involves the realistic estimation of requirements, timely procurement, availability and efficient utilization of resources. A variety of graphical techniques could be used for displaying analyzed information for management planning and control of resources. The two types of charts that could be prepared for this purpose are as follows:

a) Chart showing requirement, availability and utilization of resources for specific material like cement, steel, etc — Resource utilization chart, and

b) Chart showing the productivity of resources like men, machine, etc — Resource productivity chart.

11.2 The chart could be prepared for each selected item — category/type of resource for each activity/ work package, project component and then aggregated for the project as a whole. The information required periodically and cumulatively for the preparation of the chart is as follows:

a) Budgeted (planned) requirements (BR),

b) Actual availability (AA), and

c) Actual utilization (AU).

11.3 The budgeted requirements relate to the quantity of resource required for the work planned to be done during the budget period. The actual availability relates to quantity of resource actually available for use for performing the planned work. The actual utilization relates to the quantity of resource utilized for performing the actual quantity of work.

11.4 The resource utilization chart could be used for analyzing variation between requirements and availability, between availability and utilization and between requirements and utilization. In Fig. 26, BR minus AA can be either zero or positive or negative. If the difference between budgeted requirements (BR) and actual availability (AA) is zero, it may indicate that the resources for the activities have been provided as planned. If the actual availability (AA) is below budgeted requirements curve (BR) it may lead to schedule delays, procurement/allocation problems. If the actual availability curve is above the budgeted requirement curve (BR) it may point out non-optimal resource allocation and procurement. In Fig. 26, AA minus AU can be either zero or positive. If zero, it indicates the optimal utilization of resources. If it is positive, it shows the under utilization of resources.

11.5 The example of resource utilization chart relates to construction of cement concrete road in an industrial area and to link it with national highway. It involves widening of existing road, relocation of telephone and power lines. It involves use of different types of equipment such as batch mix plant, screened vibrators, excavators, dumpers, etc. The cost is about Rs. 11 crores, time duration is twelve months and the length of the road is 10 km. The project involves transportation of stones from near-by queries. While

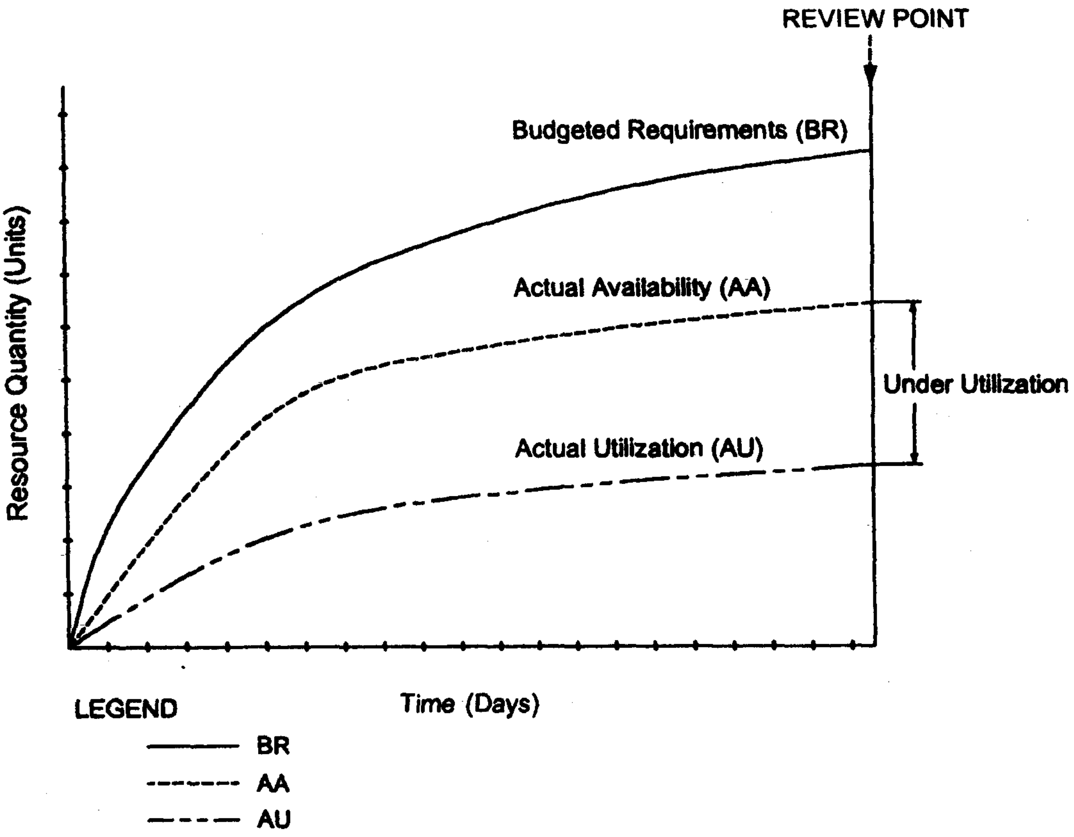

FIG. 26 RESOURCE UTILIZATION CHART

resource utilization chart would be prepared for cement as a resource, the resource productivity chart would be prepared for batch mix plant, excavators, dumpers, etc and also for men employed for the work.

11.6 Table 9 gives the monthly (both actual and cumulative) budgeted requirement, actual availability and actual utilization at the project site and the same are depicted graphically in Fig. 27. This chart depicts an example of Resource Utilization Chart for construction of cement concrete roads. From the graph, it is observed that while initially the availability of cement was less than the budgeted requirement, even then the utilization was less than the available, thereby causing under utilization of resources. The completion of the project, thus, got delayed due to shortage of material (budgeted requirement *vis-à-vis* availability). This was further compounded due to under utilization of material which may be due to additional work, equipment failures, etc.

11.7 Resource Productivity Chart

11.7.1 This chart could be prepared for resource like men, machine, etc. The information required for productivity chart relates to workload norm of each activity. The productivity of resources is expressed in terms of work done per unit of resource used, for example work done per machine hour, work done per man day/month, as compared to the norms/standards. For drawing the chart, time is indicated on the x-axis and the productivity is indicated on the y-axis. The chart shows the comparison between the actual productivity *vis-a-vis* norm/standard. A hypothetical example of Resource Productivity Chart is given in Fig. 28.

Table 9 Showing Budgetary Requirements, Actual Availability and Actual Utilization of Cement

(*Clause* 11.6)

Sl No.	Month	Budgetary Requirements (in Tonnes)		Actual Availability		Actual Utilization	
		Current	Cumulative	Current	Cumulative	Current	Cumulative
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	1	500	500	500	500	300	300
ii)	2	500	1 000	500	1 000	400	700
iii)	3	800	1 800	600	1 600	500	1 200
iv)	4	800	2 600	800	2 400	600	1 800
v)	5	1 000	3 600	800	3 200	700	2 500
vi)	6	1 000	4 600	900	4 100	800	3 300
vii)	7	1 000	5 600	900	5 000	800	4 100
viii)	8	800	6 400	700	5 700	700	4 800
ix)	9	800	7 200	700	6 400	600	5 400
x)	10	1 000	9 200	700	7 100	600	6 000
xi)	11	1 000	9 200	700	7 800	600	6 600
xii)	12	800	10 000	700	8 500	600	7 200
xiii)	13	0	10 000	700	9 200	600	7 800
xiv)	14	0	10 000	800	10 000	700	8 500
xv)	15	0	10 000	400	10 400	1 100	9 600
xvi)	16	0	10 000	400	10 800	1 200	10 800

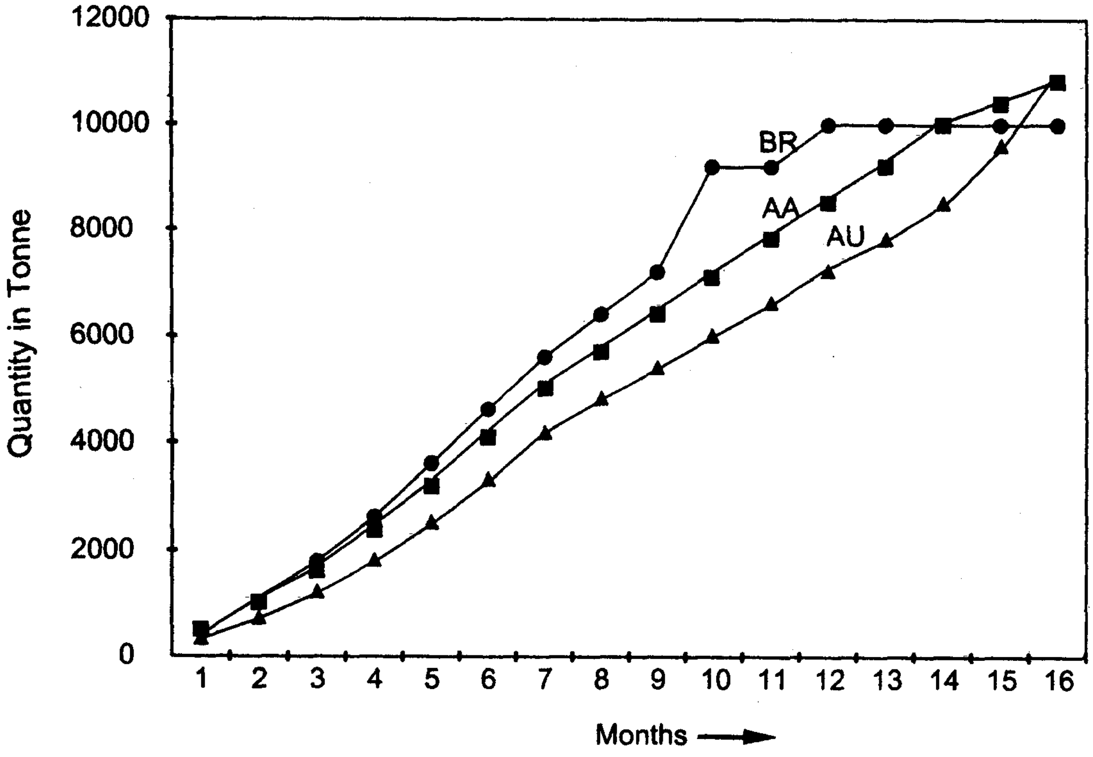

FIG. 27 RESOURCE UTILIZATION CHART FOR CONSTRUCTION OF CEMENT CONCRETE ROAD

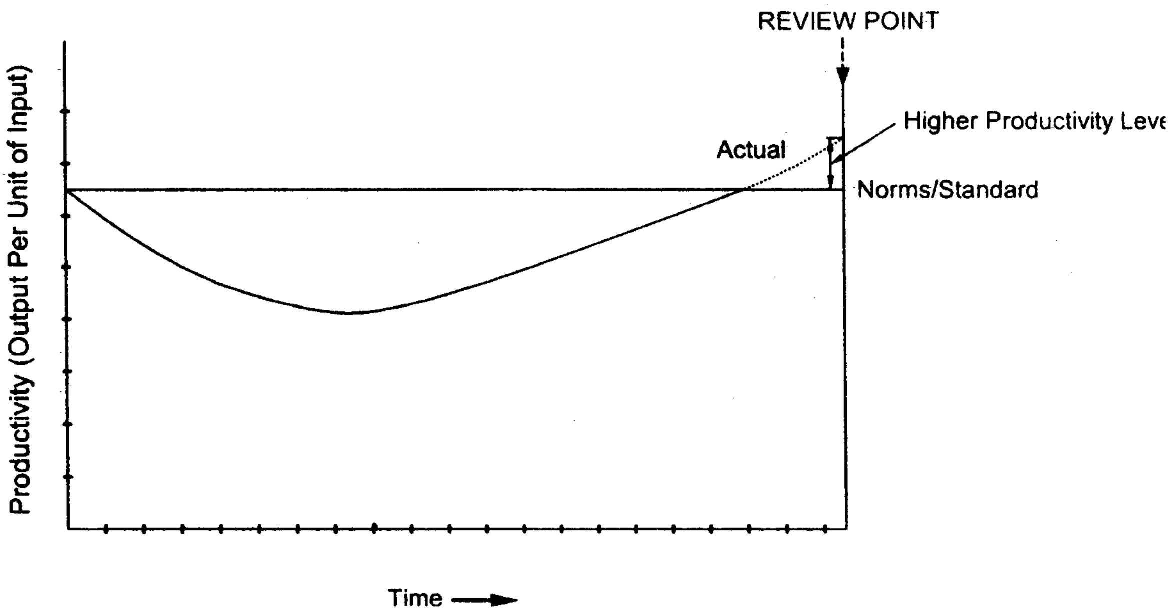

FIG. 28 RESOURCE PRODUCTIVITY CHART

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